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THE BULLETIN

OF THE

AMERICAN CERAMIC SOCIETY

Photo by J. M. McKinley

These porcelain figures were shipped in October, 1934, from Benares Hindu University, India, to the American Ceramic Society. Four months later, after correspondence between S. Dogar Singh who sent them, and the General Secretary, they were located "unclaimed" in a New York warehouse where they had been placed immediately on arrival. After many difficulties (see page 209) they finally reached Columbus, Ohio, March 20, 1935, and are prominently displayed on the exhibit shelves.

Executed with technical skill and imagination, the pieces speak well for the training given students at Benares Hindu University, which last year celebrated its tenth anniversary.

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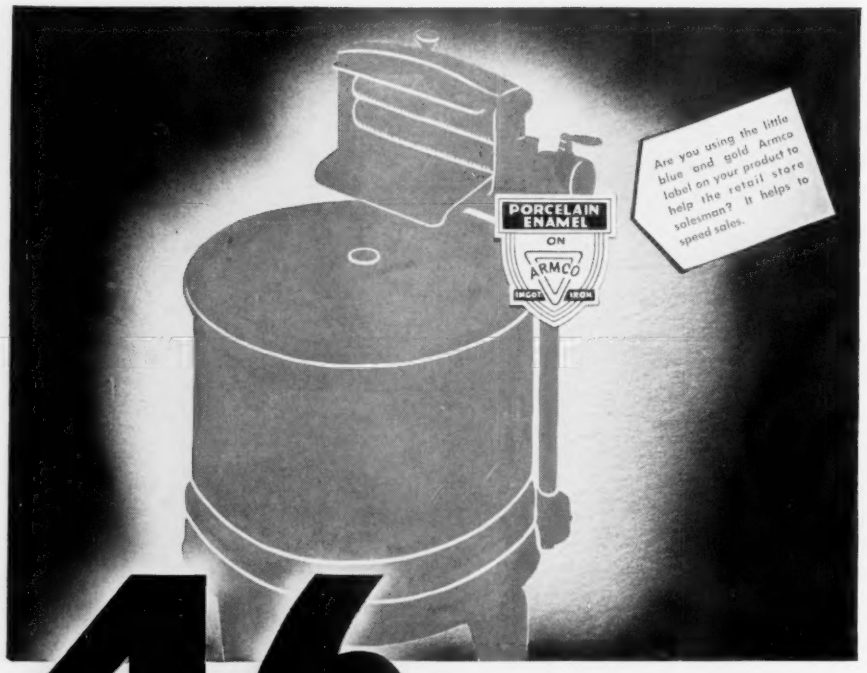
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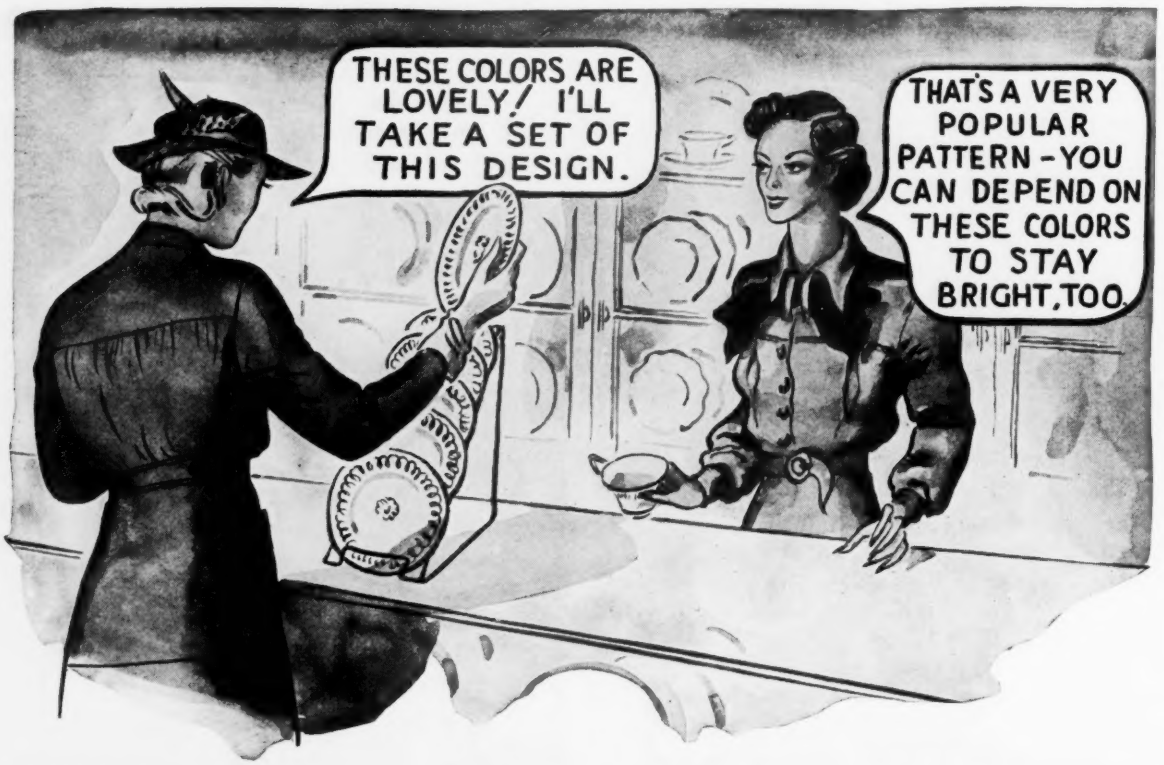
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of the Society and Promotion of Coöperative Research
of Technical, Scientific, and Art Questions

Vol. 14 June, 1935 No. 6

PAPERS

BASIC REQUIREMENTS OF THE FIRING PROCESS*

By J. A. Doyle

Abstract

More thought in terms of uniform ware and of action of heat on the surface is essential to determine better methods of heating and cooling to improve quality, and better methods of utilizing heat and handling ware to reduce cost are needed.

Uniform exposure to permit uniform transfer of heat to or from the surface is as essential as uniform temperature. Uneven circulation or radiation accounts for much variation in uniformity of product not disclosed by the pyrometer. Physical characteristics of the individual piece, or charge of many pieces, should govern the rate of heating or cooling. No one form of fuel or electricity has a monopoly on efficiency in the firing process.

I. Introduction

Basic factors in the firing process that should be recognized in light of experience, are shown in Table I, from which it will be noted that temperature is considered but one of the many factors affecting uniform ware.

(1) Time, the period required for heating or cooling, is equally as important as temperature. (2) Rate, the speed of heat transfer to or from the surface, is closely related to time. (3) Atmosphere, uniformity of composition, pressure, and rate of circulation affect both uniformity of structure and surface appearance. (4) Physical factors affecting uniformity and rate of heat transfer are as important as thermal factors related to heat.

Unwarranted emphasis on "temperature control" as the essential element in heating or cooling, and "output," "fuel consumption," etc., as determination of cost, usually lead to oversight of the influence of such factors on the individual piece or a charge of many pieces.

The viewpoint of the engineer with reference to the rate at which heat "can be transferred" to save fuel or increase production should be tempered with the judgment of the ceramist in determining the rate at which heat "should be transferred" to effect the desired result in finished ware.

II. Temperature-Time

Temperature is a more or less fixed factor determined by the nature of the process and the physical or chemical requirements in the ware. It should be considered with reference to the distinction between temperature in the chamber and temperature throughout the ware itself, which is naturally affected by the time, the method of exposure, and the rate of heat transfer.

Time and rate of heating or cooling vary in proportion to the exposed surface and variable sections of the individual piece or charge. Both are influenced by the manner of transferring heat to or from the surface, method of loading, physical characteristics of the ware, relation of one piece to another and of each to the source of heat, temperature differential between the chamber and the ware, rate of circulation, conductivity, uniformity of atmosphere, and other factors outlined by Table I.

III. Uniformity, a Relative Term

"Uniform firing" is a relative term. It is rarely obtained in the ware in practice to the extent indicated by the pyrometer.

The ideal condition is approached when the heating or cooling medium is uniformly applied to the entire surface of each piece in the same manner, at the same temperature, the same rate, the same time, in an atmosphere of uniform composition and circulation, and in equipment adapted to temperature requirements of the process, form of fuel or electricity used for generating the heat, production requirements, and plant conditions.

Although practical approach to the ideal is necessarily limited by economic conditions affecting the market for the ware, it is not unreasonable to assume that worthwhile improvement can be effected by consideration of these factors in an effort to produce better results with available equipment, regardless of the method of producing

* Presented at the Annual Meeting, American Ceramic Society, Buffalo, N. Y., February, 1935 (Symposium on Ceramic Ware Firing).

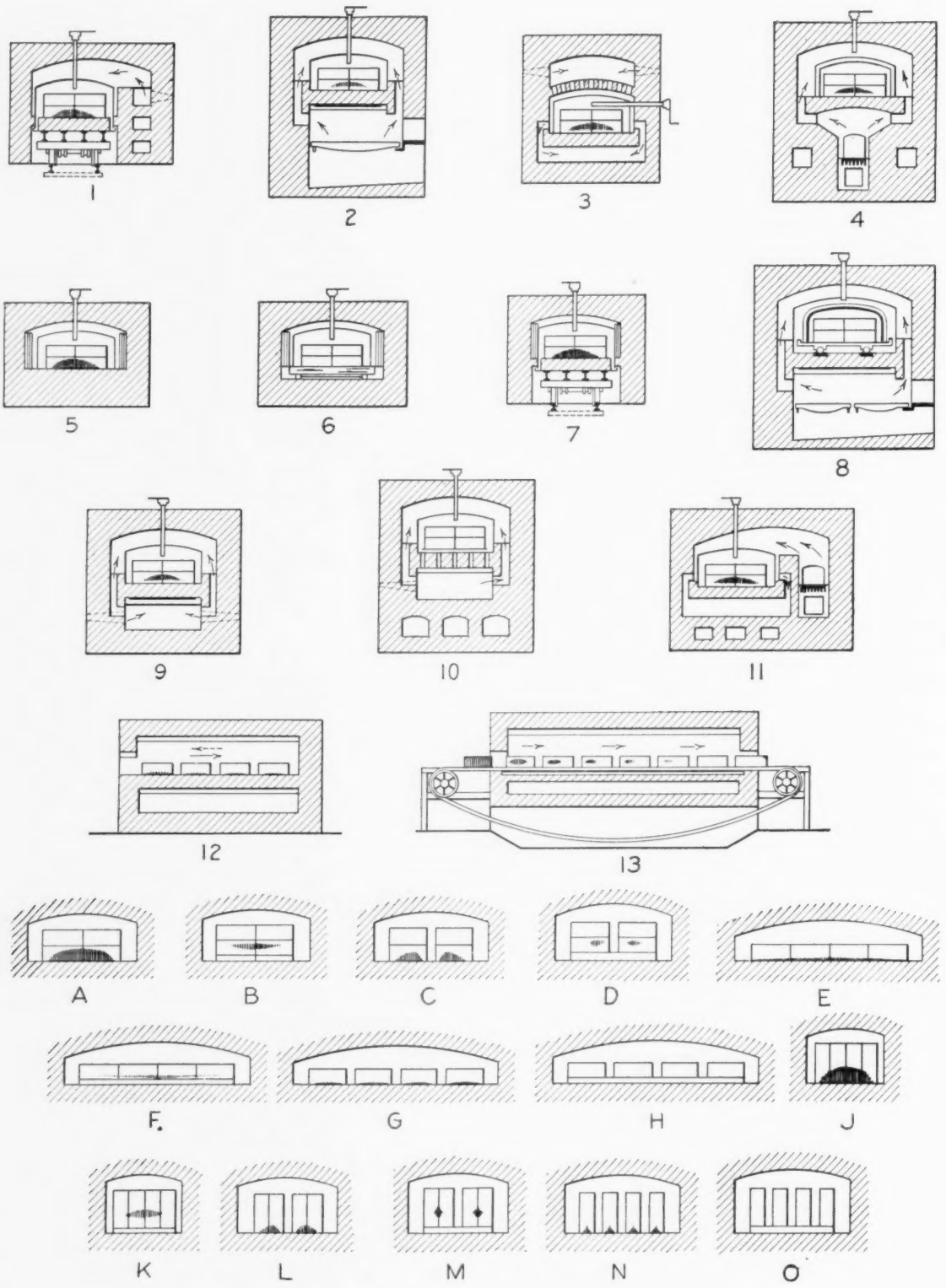

FIG. 1.—Relation of temperature indication to heated product.

The influence of furnace design and manner of loading upon uniformity of material heated in furnaces of different types, each capable of maintaining uniform temperature indication, is shown. The pyrometer chart, in each case, showed that the temperature was held constant.

heat. The economics of the individual case determines the extent of the compromise between the ideal in the laboratory and the practical in the shop, but the compromise should always be in the direction of uniform quality, lower cost with improved methods, and better working conditions for the operatives.

IV. Relation of Temperature to Other Factors

The relation of uniform ware to uniform temperature, exposure, radiation and convection, circulation, atmosphere, and kiln design is indicated by Fig. 1, illustrating

TABLE I

FACTORS AFFECTING UNIFORMITY IN HEATING AND COOLING CERAMIC WARE

- Ware
  - Temperature
    - Required in process
    - Uniformity desired in ware
  - Time
    - Surface, Section, Shape, Mass — Individual piece or charge — Heating, Cooling
    - Application of heat
      - Thermal uniformity of chamber — Heating, Cooling
      - Design of chamber
      - Position of
        - Ware in chamber
        - Combustion chambers
        - Inlet and outlet ports
        - Heating elements — Resistors, Arc, Inductors
  - Rate
    - Surface
    - Section
    - Shape
    - Mass
    - Circulation of atmosphere — Heating, Cooling
    - Moisture content
    - Conductivity
    - Saturation desired
  - Atmosphere
    - Composition
    - Rate of circulation
    - Pressure

different designs of fuel and electric furnaces in actual use with the same charge and maintaining the same indicated temperature. The pyrometric chart in each case showed that the temperature was held constant.

Although it is generally assumed that the charge would be uniformly heated in any furnace, there is marked variation in uniformity in each of the several furnaces, even though the indicated temperature and time of heating are the same. The difference is due to different methods of "heat application," *i.e.*, applying heat to the surface of the charge.

Approximate location of incompletely heated zones is illustrated by the shaded sections. Electric furnaces 5, 6, and 7 are not exceptions to the rule, for while they are alike in method of generating and controlling the heat, they differ in method of heat application.

The product will likewise vary in uniformity in each furnace with different methods of exposure, even though there be no variation of indicated temperature. The time and rate of heating and cooling, effect of atmosphere, or of irregular radiation or convection will differ in each instance. Diagrams *A* to *O* (Fig. 1) illustrate variations in uniformity and time, resulting from different methods of exposure to the same chamber temperature.

Another simple illustration of this point is Fig. 2, indicating four identical coils of metal placed in different positions within the same chamber. Each one heats and cools at a different rate and in a different manner, each responds differently to the influence of atmosphere, circulation, and local radiation from an inlet port or a resistor, even though the temperature indication is uniform. Coil *C* should show the best result in uniformity of structure and finish and in less time because of relatively uniform exposure.

Uniform pyrometer records may serve as evidence, but not as proof, of uniformly heated products.

V. Influence of Physical Factors

Physical factors related to mass, surface, and section of the individual piece or charge affect the rate of heating and cooling and influence of atmosphere. Variations in physical proportion, or method of exposure, necessarily call for variations in the rate of transfer to effect uniformity.

The instinctive act of a hen in turning eggs in the hatching process to offset the effect of a slight differential in temperature (and atmosphere) of the nest and body, which affect uniformity of the incubating process, is a

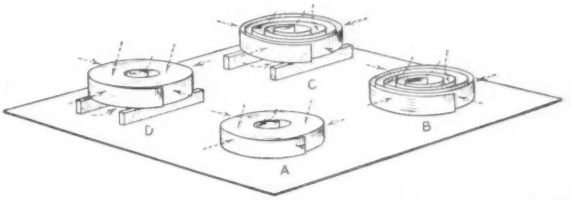

FIG. 2.—Different methods of heating and cooling coil of metal.

striking lesson on the influence of physical factors on uniform "heat application."

The natural defect in good heating practice (due to the difficulty in sitting on both sides of an egg at the same time), making it necessary to turn the egg to the source of maximum temperature for uniformity, is corrected in continuous incubators applying heat to the individual egg under conditions of uniform exposure and uniform temperature, time and rate of heating, atmosphere, and rate of circulation.

The sense of the hen, or the cook in the kitchen, could well be considered in a study of physical factors in firing practice which should be based on thought of uniform products, not merely uniform pyrometer charts, fuel records, or the thermal tommyrot of sales rackets that has clouded the thought of fundamentals affecting production of better and cheaper products.

Physical factors affecting absorption or release of heat are as important as thermal factors in the process of firing.

VI. Uniform Exposure Desirable

Uniform exposure is as desirable as uniform temperature, time, rate, or atmosphere; otherwise, the amount of heat absorbed and the effect of atmosphere may vary even though the pyrometer indicates a uniform temperature,

the clock a uniform time, and the recorder a uniform gas analysis.

The relation of temperature at the bottom and center of a charge to that indicated by a cone or pyrometer on the outside should be considered in determining the manner of loading and the time and rate of heating or cooling.

Smaller charges, more uniformly exposed and separated, tend to more uniform ware in less time.

It is as unreasonable to expect uniform heating or cooling of a large closely packed charge as it is to expect hay or brick to dry uniformly in stack form.

Better methods of loading to expose the ware more uniformly to the action of the heat or to permit the atmosphere to circulate through the charge are likely to react in better results with existing equipment. Regardless of whether the ware is brought to the heat or the heat is brought to the ware, uniform application to the surface is necessary for uniform product.

The principles that govern uniform drying hold with equal force in the firing operation.

VII. Atmosphere

Atmosphere should be considered with reference to uniform composition and application to the surface of the ware.

Time and rate of heating or cooling affect the action of the atmosphere substantially the same as does temperature.

Uneven circulation may react in uneven heating, cooling, or color.

Oxidation is not entirely a matter of atmosphere as is usually assumed. Composition of an oxide on metal reflects the nature of the atmosphere affecting the surface, but the amount of oxide is greatly influenced by the time of exposure and rate of circulation. The principle holds good with reducing atmosphere or other types as it does with one that is oxidizing.

Uniform atmosphere, like uniform temperature, is a relative term in practice.

VIII. Influence of Circulation

Uneven circulation accounts for much irregular heating and cooling and surface appearance that is not disclosed by the pyrometer or by gas analysis. It is more pronounced on the thinner sections of the individual piece or on pieces outside the charge.

Circulation is affected by many factors, including design of the kiln (fuel or electric), method of loading, temperature differential, position of inlet and outlet ports, localized luminous flame, uneven draft, irregular radiation position of resistors in electric furnaces, etc.

There is much to be learned by a study of factors affecting uniformity of circulation and pressure of atmosphere and the combined effect of radiation and convection in both fuel and electric kilns.

Uniform circulation, composition, and pressure of atmosphere are closely related to uniform ware.

IX. Radiation *vs.* Convection

Both radiation and convection influence the operation of the average fuel or electric kiln. Conduction plays a part mostly within the ware itself.

Much of the virtue attributed to radiation should be credited to convection. Heating by radiation alone frequently has the effect of toasting bread or broiling a steak over a bed of live coals or of heating a room from an open fireplace or portable electric heater.

Uneven radiation usually accompanies (1) temperature differential between the ware and the fire box, combustion chamber, or inlet ports of fuel-fired furnaces, (2) luminous flame not equally applied to surface of the ware, (3) resistors of electric furnaces, and (4) other sources of local heating.

Uneven convection is frequently due to causes responsible for uneven radiation and to other causes, such as location of outlet ports, uneven draft, uneven circulation of atmosphere, etc.

Correction of uneven heating due to uneven circulation or radiation is of more practical value to the industry than abstract discussion of the thermodynamics involved. As with the commercial problem of relative fuel values, the usual discussion is equivalent to a debate on the comparative merits of wine and water as a beverage. Each has its place.

Uniform application to the surface of the ware is the objective with radiation or convection, just as it is with temperature or atmosphere.

X. Kiln Design

Kiln design and operation in the future should be based on the consideration of the need for more uniform ware from the viewpoint of the ceramist and sales staff. The cost of production will decrease with better methods of utilizing heat and improved structural design that will naturally follow.

Accepted standards for defining kiln "efficiency" in terms of fuel consumption, heat balance, output, temperature control, atmosphere, etc., without regard to uniformity of the ware itself, are questionable.

Disregard of this point accounts for variation in ware from modern fuel and electric kilns provided with practically everything known to science for producing heat uniformly.

No one form of fuel or electric kiln is likely to be acceptable as standard. Quality standards, production requirements, and plant conditions vary so much that it is usually necessary to deal with each problem on its merits.

The basic requirement of the ability to apply heat to the ware with reasonable uniformity at capacity load should be the controlling factor, regardless of the size, structural features, or method of heating.

XI. The Fuel Problem

Selection of fuel for firing ceramic products has long been based on standards that are economically unsound and retard development.

There is no definite relation between quality and uniformity of ware and any one form of fuel, electricity, or kiln. Each has its limitations.

Firing is accomplished with heat; not with fuel or electricity. They are but the means to an end.

The discussion of alleged relative merits of different forms of fuel or electricity, prompted by competitive commercial conditions, is largely beside the point and

clouds the real issue. The relation is constantly changing with development of modern designs of furnaces and kilns.

Comparisons made with claims for advantage of one over another are frequently, in effect, but a comparison of specific types of furnaces operating under specific conditions. The relation may change with different furnaces or methods of operation in the same plant at the same time with the same product.

Standards that test efficiency in industrial heating operations differ radically from those applicable to the use of heat in other operations, such as generation of power or heating buildings. Although fixed in principle, they are somewhat indefinite and variable in application. Heat treatment is affected by many intangible factors not common to other heating operations. Variety of equipment design is much greater. Standardization is possible to a decidedly limited extent because of the many variable factors involved.

A change in fuel or method of generating heat in the expectation of producing better ware should not be made without study of the kiln design as to the probable action of heat on the ware. Frequently a change in fuel means little more than a process of continuing to do a poor job of firing more conveniently.

The "technical sectarianism" reflected in the evangelical fervor of die-hard advocates of any one form of fuel or electricity, without regard to other essential economic factors, justifies the assumption that the fundamentalists of evolution or prohibition have much in common with these brethren, the "technical fundamentalists," who so frequently forget that firing is performed with heat, not with fuel.

Until such time as we can accept some one form of fuel, electricity, or heating equipment for the relatively simple heating operations in the ordinary household, it is economically unsound and ethically questionable to foster propaganda calculated to form the impression that any one form of fuel or electricity has a mortgage on efficiency in the far more complicated industrial heating field.

The so-called "fuel problem" will be solved as the industry learns to sense the difference between the price of fuel or electricity and cost of heating, to understand the distinction between generation, utilization, and application of heat, to think in terms of uniform heating and cooling, and to appreciate the influence of kiln design and operation on quality and cost of ware.

No one form of fuel or electricity has a monopoly on efficiency or economy in the firing process. It is the design and operation of the kiln, not the fuel, that controls quality and cost of the product.

XII. Influence of the Human Element

The human element is, and long will continue to be, a controlling factor in the firing process, even with kilns provided with automatic temperature control, except in the operation of continuous kilns with products of uniform physical characteristics.

Variation in size, shape, quality, quantity, or composition of ware calls for (1) judgment in loading and time and rate of heating and cooling, (2) uniformity of atmosphere, and (3) rate of circulation.

Kiln operators of higher type are desirable. Saving in fuel, scrap, labor, maintenance, etc., with intelligent supervision, more than pays for the higher cost.

Kiln operation is good training for the young engineer on whom we must depend for a needed new perspective uncontaminated with traditions of the firing process that have too long outlived their usefulness. In addition, it is an effective method of sweating out of his intellectual system some of the misinformation on firing acquired from books based on other books and trade publications that ignore the distinction between "making heat" and "heating ware."

The industry could profit to decided advantage if fuel-fired furnaces were operated with the relative intelligence disclosed in the heating process of the average household.

XIII. Conclusion

This statement appears justified in light of the state of the art and precedent of accomplishment in other fields governed by the same basic principles, because of the astounding waste that could be avoided with practical application of the obvious in firing practice that would lead the industry to more money with less grief.

As it is generally admitted that something is wrong with the average firing process and that modern equipment and methods of generating and controlling heat have failed to produce desired results, it is in order to encourage thought of fundamentals in the belief that the ceramist may sense the way out of the woods.

We have lost our way in firing practice because of the technical tanglefoot and confusion of irrelevant discussion in the commercial Tower of Babel and the merry-go-round of sales rackets that have led the industry to think of almost everything related to heat but the action of heat in the ware itself.

The ancients that sacrificed a goat to appease the wrath of the gods in hope of producing uniformly fired ware are the technical ancestors of the moderns who offer a pyrometer record to appease the wrath of the customer who refuses to be a goat in the belief that evidence of uniform temperature on the chart offsets proof of uneven firing in the ware itself.

We must sense the distinction between mere thermal technology and basic principles governing production of better and cheaper ware, and, as with our economic problem, get back to fundamentals as the basis of a new deal that will lead to progress and profit in development of one of the oldest, most important, misunderstood, and long neglected of the industrial arts.

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EFFICIENCY OF KILNS*

By F. A. Whitaker

Abstract

A definition of the efficiency of industrial furnaces with special reference to kilns is presented. The difference between efficiency and effectiveness is brought out, a comparison is made of periodic and continuous kilns, and the minimum requirements of the latter are given with a review of the sources of heat losses.

I. Introduction

In modern industrial, economic, and sociological parlance, efficiency expresses a concept, different from its older general sense, of the function of producing desired effects or effectiveness. In its later mechanical sense, in which we are mainly interested, efficiency is the ratio of useful work performed to the energy expended or, more briefly expressed, the ratio of output to input.

Efficiency in its newer usage recognizes the mechanical idea of balance between energy furnished and work or energy returned, but it recognizes a'so that unpreventable losses occur in every cycle of operation and it does not charge these against the efficiency of the process or agent which must work in that cycle. Efficiency is an effort to discover and remove preventable losses and wastes, so that the largest returns may be secured for the least expenditures. Its main function must be to cut off unfruitful expenditures of energy and to save output which has been wasted on something different from the desired purpose.

(1) Effectiveness

This distinguishes efficiency sharply from effectiveness, which, *per se*, is only the achievement of result by increase of input without any necessary consideration of the actual expenditure incurred. An effective performance, however, may also be an efficient performance. On the other hand, an effective performance may be inefficient if it wastes resources in reaching its achievement, and an efficient performance may be ineffective because, though it conserves and applies its resources with the utmost skill, the resources available are insufficient for the work in question.

(2) Specific and Generic Efficiency

Furthermore, we must distinguish between efficiency in a specific sense and in a generic sense. By the former is meant a case where a definite amount of heat must be imparted to a certain weight of clayware to heat it up to a certain temperature, in which case the ratio between the efficiently utilized heat and the heating value of the fuel consumed is the efficiency of the kiln. If the kiln is electrically heated, the theoretical heat value of the electric energy is the divisor.

Cases of generic efficiency are those in which practically all of the heat generated eventually leaves the kiln again, that is, when a certain temperature has to be maintained for a long period after the ware has been heated up, *e.g.*, the long soaking of silica brick. It is obvious that there is no definite term, expressible in calories, to compare with the thermal power of the fuel if no more of the generated heat is imparted to the ware. Kilns doing this kind of work, of course, can be exactly compared with each other, and if one does the work with 20% less fuel it is so much more efficient, although we cannot speak of the absolute or specific efficiency of the kiln.

In many cases the two efficiencies are combined in the same operation and then the calculation of absolute efficiency can be made for that portion of the operation wherein a certain definite amount of thermal work is done.

II. How to Increase Kiln Efficiency

If the efficiency of the periodic kiln is only 15%, we search for the leaks in an effort to regain some of the lost 85%.

(1) Kiln Brickwork

Not only the ware and saggers but also the walls, bottom, and crown of the kiln must be heated. This mass of brickwork absorbs a large percentage of the heat units.

In the continuous chamber type of kiln, in which the ware is stationary and the firing is advanced from chamber to chamber, part of this loss is recovered by the combustion air, which previously has cooled the ware by absorbing heat

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from it. At the same time the products of combustion preheat the ware in the chambers ahead on their way to the stack. In the railroad tunnel kiln, this loss is entirely eliminated for the walls and crown after they have once been heated up to operating temperature.

A large percentage of heat absorbed by the car platforms is recovered in the cooling zone of the tunnel kiln by the cooling air which is then conveyed partly back into the kiln and the remainder is used for drying clay and ware and for heating the building in winter.

All heat units which are recovered outside of the kiln naturally should be credited to the kiln, since the fuel otherwise needed for heating the drier, for making steam, etc., is saved.

(2) Products of Combustion

The products of combustion also amount to a large percentage in the periodic kiln, which increases with the temperature to which the ware has to be heated, because heat absorption decreases as the temperature difference between heating gases and ware decreases and therefore losses increase as this difference decreases. For instance, the high efficiency of steam boilers is mainly due to the fact that the heat-absorbing medium has a temperature of only about 350°F. As long as the ware averages this low temperature, the heat absorption in the kiln is also comparatively large, resulting in low temperature of the waste gases. This condition, however, lasts only a short time and when the surface of the ware, saggers, and kiln lining have reached the maximum temperature desired for the ware, the waste gases begin to exceed this high temperature which averages 2000°F or more. These losses can be exactly calculated from the average temperature, weight, and specific heat of the waste gases.

Most of these losses are recovered in the continuous kilns by using the waste gases for preheating the ware. In the chamber type of continuous kiln, the temperatures of the waste gases are kept just high enough to produce the necessary chimney draft. When using fan draft the temperature can be further reduced, and in the chamber kiln it measures 140°F at the fan. In the tunnel kiln, the waste gases normally leave the kiln at between 250 and 300°F, so that no condensation can occur on the cold ware. Before reaching the fan, however, the waste gases are utilized still further for drying ware and leave the fan at between 100 and 150°F. This is another recovery of heat units outside of the kiln, which should be credited to the kiln.

(3) Radiation from Walls and Crown

This loss is also rather large in most periodic kilns and 80 to 90% of it probably takes place through the crown, which rarely is as heavily insulated as the kiln walls and quite frequently not insulated at all for several good reasons.

(1) In some cases it has been found that heavy insulation shortens the life of the crown considerably.

(2) As insulation naturally preserves a higher temperature below the crown, this tends to increase the difference between top and bottom temperature in downdraft kilns where the temperature is always highest under the crown, so that the insulation often is purposely omitted to lessen this difference. Some plants go even further by letting some of the extremely hot gases escape through vent holes in the crown to reduce pressure and temperature below, and these gases escape before they have done any useful work in the kiln.

(3) Insulating the crown has been known to more than double the cooling period of periodic kilns with a resultant slowing up of production.

In addition to maximum insulation of continuous kilns, we should use a material on the outer wall surface which will not readily give up its heat to the surrounding air. Heat is dissipated from outside walls both by radiation and convection and the sense of touch is often misleading; *e.g.*, a polished metal surface will dissipate less heat than a considerably cooler brick surface, though the metal feels hotter.

Great savings are made in this respect in modern continuous kilns. The chamber type of the continuous kiln lends itself to the adoption of semicircular or other strong crowns, which are less endangered by high temperature and are always well insulated. In the tunnel kiln the arch is as well insulated as the side walls, so that men can comfortably walk on top of the hot zone. Furthermore, the radiation losses through the side walls of tunnel kilns are less than through the walls of an equally well-insulated periodic kiln, because the firing zone in a tunnel kiln comprises only from 10 to 15% of the kiln length and the gases pass immediately from this zone into the preheating zone, giving off the heat to the cold

ware, gradually decreasing the temperature of the side walls, which, in turn, decreases radiation losses. In places where certain radiation losses are to be expected, as opposite fireboxes, some of these losses might be recovered by using the dissipated heat for drying purposes, in which case this recovery should also be credited to the kiln.

(4) Conduction into the Ground

If kilns are built directly on the ground, a considerable amount of heat might be carried away by underground waters. If not, the heat might penetrate very deep into the ground unless proper insulation is provided. In this respect, a continuous type of kiln has no advantage over a periodic kiln and in one instance where a ring kiln was built directly on the dry ground the heat was found to penetrate to a depth of 30 feet.

In a car tunnel kiln these losses are reduced to a minimum by providing heavy insulation between the car and its refractory platform and by utilizing the hot air below the cars.

(5) Loss through Kiln Openings

Heat losses caused by cracks in the brickwork, etc., are generally underestimated, especially if the kiln is under draft. As long as a kiln or parts of it are kept under pressure, the losses are clearly apparent to the eye or touch, when flames, smoke, or hot gases are seen pouring out of many places, although their only exit should be the stack. These heat units are lost before they can do the work intended for them. Instead of closing the openings, the operators usually resort to increased draft, which makes these losses invisible to the eye, but they generally are much larger than with pressure, as the large percentage of excess air, which has to be heated up to kiln temperature, carries many heat units up the stack, especially at the higher temperatures.

It is much easier to prevent cracks in a continuous car tunnel kiln in which firing conditions are nearly always constant than in a periodic kiln or a chamber-type continuous kiln, which is alternately heated and cooled. If a tunnel kiln has been shut down for some reason, any cracks which might have formed should be immediately closed.

Any smokeless stack might mean a great waste of fuel due to excess air. One frequently finds 250% excess air in the waste gases where 50% would have insured a sufficiently oxidizing atmosphere when gas or oil are used as fuel. In case of oil fuel, assuming a stack temperature of only 800°F, this air means a fuel loss of about 30%. It is therefore advisable to check the excess air continuously by means of a CO_2 recorder.

There is a possibility, however, that a CO_2 recorder will always show the desired minimum excess air required for oxidizing firing and that some of the ware nevertheless shows signs of reducing conditions, which might be caused by reduced firing in one of the fireboxes, as the instrument usually only shows the average of all fireboxes.

A recorder would therefore be needed for each firebox unless each one is kept in exactly the same condition, which is comparatively easy with gas or oil firing in a tunnel kiln.

(6) Incomplete Combustion

Incomplete combustion losses are practically unavoidable whenever coal is fired, except when in powdered form, as tests of most ash piles will show. Additional fuel is carried up the chimney in the form of smoke, soot, or carbon monoxide. The latter condition is unavoidable in periodic kilns that require reducing firing atmosphere. The percentage of CO in the flue gas cannot be a direct measure of the loss due to incomplete combustion, because in the incomplete combustion of a fuel, consisting mainly of hydrogen with but little carbon, there would only be a trace of CO, even at very incomplete combustion. The true measure of loss due to CO is the ratio of the volume of CO in the flue gas to the maximum volume of CO_2 which would be produced by complete combustion.

In a continuous kiln, the reducing atmosphere can not only be kept more constant, incurring minimum losses, but can easily be confined to the firing zone or to certain sections of the firing zone or preheating zone if desired.

III. The Tunnel Kiln

A tunnel kiln can be economical in the long run only if it is designed to meet practically all conditions arising at the plant. It must not be too large, so that it can be operated at full capacity most of the time. It must be flexible enough in capacity to produce perfect ware down to one-third of normal capacity and must be at least as economical in operation at this low capacity as a periodic kiln is at full capacity. It must be low

in initial cost and as simple in design as is consistent with the desired results.

Tunnel kilns should be so designed that they can be efficiently operated by unskilled labor with minimum attention. They are not only adaptable to large plants, but can be designed for capacities equivalent to one or two periodic kilns at comparatively low cost, especially when they are of the open-fire type in which the gases are uniformly distributed between the ware or saggers. Since the latter form an insulation around the ware and absorb much heat themselves, open setting naturally reduces the kiln cycle which in turn reduces the kiln size and its initial cost.

The temperature gradient from the heat source to the ware should be as slight as possible, and this requirement can only be met by circulation of the hot gases among the ware, in which case most of the heating occurs by convection.

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EFFECTS OF COMBUSTION METHODS ON TEMPERATURE UNIFORMITY OF KILNS AND FURNACES*

By F. O. Suffron

Abstract

The results of several years of research in the fundamentals of gas combustion under the auspices of the Industrial Gas Research Committee of the American Gas Association are related to the practical application of gas-combustion principles in kiln firing. The factors influencing heat transfer from the products of combustion to the ware are discussed, as well as the effect of design, type of combustion, and secondary aeration on the uniformity of heat distribution and atmospheric control.

I. Introduction

Note: Whether the basic research yielding fundamental knowledge precedes practical applications or follows crude makeshift developments, there seems to be little doubt but that research is essential if an industry or any component thereof is to enjoy a continued and substantial growth.

Several types of city gases are distributed in the United States, the principal classification being natural, manufactured, and mixed gases. In any given locality, however, a single gas is distributed, the type being governed largely by available sources of supply and distribution conditions as well as from the standpoint of providing the most economical service to consumers.

The sensitivity of temperature control provided in any industrial heating process is influenced to a large extent by the design and kind of control equipment employed. Gas, with its intrinsic merits, may be satisfactorily applied in many installations by simple piping and control layouts. For more precise regulation, especially automatic or semi-automatic, it is essential to utilize controls of a more complex nature. In this, as in all other respects, the requirements of the process must dictate the type of application to be made.

Requirements in many ceramic processes are that the temperature at any one point in a work chamber shall deviate but little from the temperature at any other point and that work-chamber atmospheres must be controllable to any predetermined value. The former condition is uniformity of heat distribution. To study the effect exerted by gas-combustion methods on these important factors of heat distribution and atmosphere control, it is necessary to examine gas-combustion phenomena carefully.

II. Gas Compositions

City gases are composed of hydrocarbons, hydrogen, carbon monoxide, and incombustibles, such as carbon dioxide, nitrogen, and oxygen. The combustible constituents of natural gas are largely methane and ethane, whereas carbon monoxide, methane, and hydrogen generally predominate in manufactured gases. The molecular reactions of these various constituent gases,

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as well as of city gases with air, are widely published and consequently need no treatment here.[1]

III. Ways of Burning Gas

Aside from special applications, gas is burned in three basic ways: (1) when the air required for complete combustion is furnished entirely as primary air, *i.e.*, air supplied to the gas before the combustion zone; (2) when only part of the combustion air is provided as primary air; and (3) when no air is mixed with the gas prior to the combustion zone. This latter condition yields a luminous or so-called yellow flame which finds many applications. Its luminosity is caused largely by the liberation of carbon particles which are heated to incandescence. Combustion of gas will be completed by this method provided that sufficient secondary air is available and that partially fired products are not cooled below their ignition temperature.

(1) Bunsen Flame

For ceramic processes, combustion of air-gas mixtures in which all or some part of the air required for combustion has been supplied as primary air seems to find favor. The Bunsen flame, in which a phase of the combustion reaction is completed with secondary air, has been carefully studied by many investigators. Theory indicates that combustion of gas in a Bunsen flame is accomplished in two distinct reactions. Partial oxidation of the combustible constituents of a gas by primary air injected into the air-gas stream before the combustion zone is effected at the surface of the inner cone. The incompletely burned constituents, carbon monoxide, hydrogen, alcohols, and aldehydes, which are emitted from the surface of this inner cone, become completely oxidized by their mixing with secondary air. This secondary reaction can only be completed when the supply of secondary air is adequate and when the temperature of the unburned products surrounding the inner cone is maintained above their ignition temperature until final oxidation is completed. Thus a relatively cold object placed in the mantel of a Bunsen flame will result in incomplete combustion and the liberation of reducing products irrespective of the amount of secondary air present.

An operator, utilizing gas flames of this character, must exercise considerable care, if certain kiln-atmosphere requirements are to be met. Assuming that work requires heat treatment in an oxidizing atmosphere, the combustion reaction must be completed before the products of partial combustion come in contact with the work. The possibility of part of the work being enveloped in a reducing atmosphere otherwise exists. Furthermore, it may be seen from the preceding fundamental concepts of combustion that the admittance of secondary air must occur, if the combustion reaction is to be completed at a point in the work chamber before the mixture has cooled below the ignition temperature of any of its combustible constituents. From available data it appears that the ignition temperature of commercial gas-air mixtures may, under certain conditions, be above 1200°F. Consequently, an endeavor to obtain a condition of progressive combustion in a kiln by judicious admittance of secondary air at various points therein may result in reducing products at some point or points in the combustion chamber, due to either of the above-mentioned possibilities.

IV. Inefficiency of Secondary Aeration

It should also be brought out that secondary aeration, as compared with primary aeration of a flame, is inefficient. Considerably more secondary air than can possibly enter into combustion due to lack of intimate mixing must be admitted if combustion is to be completed. While an abundance of secondary air may be desirable in some cases from the standpoint of uniformity of heat distribution, it certainly does not provide the optimum conditions for economical operation in ceramic kilns.

Combustion of the air-gas mixture, in which all of the air theoretically required for complete combustion is supplied prior to the combustion zone, is distinctly and fundamentally different from that occurring in the Bunsen flame, since it occurs entirely at the surface of the inner cone (a well-defined zone of reaction). The mantle observed about this inner cone of the flame is comprised only of completely burned flue gases which are incandescent by virtue of their high temperature. This leads to the significant fact that completeness of combustion of a theoretical air-gas mixture can not be directly affected by physical interference with the flue gases in this outer incandescent zone. Consequently, from

[1] See Combustion, 3rd ed. Published by the American Gas Association.

the standpoint of securing complete combustion of such a mixture, the combustion chamber walls need be no larger than necessary, consistent with proper design, to encompass the surface of the inner or primary cone.

V. Control of Atmospheres

Control of atmospheres in a kiln may be easily and accurately maintained by suitable regulation of the air admitted to burners. Reducing atmospheres will result from diminishing the quantity of air below that amount required for complete combustion, and oxidizing atmospheres will result from increasing it above that quantity. Wherever close atmospheric control must be obtained, it is essential to give full consideration to the dissociation of water-vapor and carbon dioxide in the products of combustion of any fuel.

Generally accepted laws covering the dissociation theory have been developed.[1] Briefly stated, a definite percentage of carbon dioxide and water-vapor is theoretically dissociated to carbon monoxide plus oxygen, and hydrogen plus oxygen, respectively, under any given set of equilibrium conditions of partial pressure and temperature. It is apparent from theory and experimental data that dissociation of these constituents is accelerated by rising temperatures and, on the other hand, is repressed by admitting increased percentages of excess oxygen to the air-gas mixture.

During all investigational work at the American Gas Association Testing Laboratory involving oxidizing atmospheres, the concentration of carbon monoxide plus hydrogen in the flue gases was held to exactly 0.05%, by supplying small quantities of excess oxygen. This exactness with which reducing constituents may be controlled in the industrial use of gas is noteworthy. With the combustion of other fuels or of gas with partial primary aeration, precise control of this factor of dissociation is difficult and in many cases impossible.

Another consideration is that dissociation of CO_2 and H_2O is a reversible reaction and only comes to a state of equilibrium when the flue-gas temperature and partial pressure remain constant for a definite period of time. Although partial pressures will remain fairly constant, the temperature of the flue gases at the outlet of a kiln may be lower than in the kiln itself. Since reversal of the reducing products to carbon dioxide and water-vapor occurs with decreasing temperatures, absence of reducing products as evidenced by analysis of flue gases at the outlet does not indicate that such constituents will not be present within the kiln where higher temperatures prevail.

Considerable data have been collected from which can be found the amount of excess oxygen that must be admitted to an air-gas mixture in order that no more than 0.05% carbon monoxide plus hydrogen will be produced. The amount of excess oxygen necessary for this purpose is very small and, furthermore, can be accurately determined and precisely regulated. These data are also significant since they show that for equal heat liberation, the amount of excess oxygen required for complete combustion of a totally premixed air-gas mixture is not only extremely small but is entirely a function of temperature and independent of variables such as fuel gas, size and shape of combustion chamber, type and size of burner, and combustion chamber-wall temperatures. Although these latter factors influence flue-gas temperatures, they have no direct effect on combustion.

In consolidating the pertinent facts of the foregoing discussion, a valid conclusion of practical value is that combustion of an air-gas mixture in which the percentage of air is equal to that theoretically required for complete combustion will be completed in a limited and definite zone or combustion space. Contact of flue gases emitted from this zone with any object will not affect their composition to any measurable extent. Dissociated products, which are present in high-temperature flue gases resulting from combustion of any fuel, are of so small a magnitude as to be negligible in the ceramic field. Nevertheless, if and when it becomes necessary to limit or eliminate them, it can be readily done with proper control of gas combustion. Finally, a conclusion which seems to be extremely important for direct firing of ceramic ware is that combustion of the type being discussed is not only controllable at any one point but will afford uniform atmospheres throughout a kiln. Obviously, delayed or progressive combustion must by its very nature yield atmospheres of a continually changing composition.

The feasibility of controlling atmospheres independently of heat-distribution problems permits consideration and solution of such problems without allowing for the confusing and sometimes irrec-

oncilable factors which are often introduced when atmospheres and heat distribution are interrelated by the nature of a combustion process.

VI. Uniform Heat Distribution

Uniformity of heat distribution is apparently of primary importance in the ceramic field. In many processes it has constituted a most difficult problem. From an academic viewpoint there appears to be no basic reasons why the strictest temperature and heat-distribution requirements can not be completely fulfilled by proper application of gas in practically all industrial heating processes. Difficulties encountered have been largely due to limited knowledge of the possibilities afforded.

We shall consider only direct firing methods, inasmuch as they present the most severe conditions from the standpoint of uniformity of heat distribution and give promise of maximum economy. The principles brought out in the following discussion, however, are equally applicable to other methods of firing.

With direct firing, as in all other methods, heating of ware is accomplished by convection, radiation, and conduction. With any form of fuel or energy, each of these methods of heat transfer will be a factor. It is essential, especially where the factor is of large magnitude, to exercise every care in design and operation to insure that the heat transmitted by the method under consideration is uniformly imparted to the work.

(1) Radiant Energy

Considering radiant energy for the moment, it is apparent that if every portion of all surfaces of work is to receive the same amount of heat by radiation, provisions must be made to have a spherical source of uniform intensity. Unless such an ideal condition exists, certain portions of work must be heated by conduction through the work itself, which in turn will set up a pronounced temperature gradient. That temperature gradients of some magnitude will exist in work during certain periods of heating cycles and regardless of firing methods is, of course, recognized. The problem is to reduce this temperature gradient to a minimum. Then too, the percentage of radiant energy absorbed by work depends on the emissivity coefficient of the work, source of heat and work temperatures, and, to some extent, wave-lengths of the radiant energy. The emissivity or absorptivity coefficient varies with different materials as well as with surface finish of a given material.

Heat transfer by radiation possesses some advantages. For direct firing, however, the practical difficulties of securing uniform thermal history are somewhat greater where heating is done largely by this method.

(2) Heating by Convection

Heating with convection as a primary medium is, from an academic viewpoint, also of complex nature. It is common knowledge that gaseous film, or "dead air" space, surrounding all solids, offers resistance to heat transfer. Heat flows through such a film only by conduction, and the rate at which heat can be so transferred is proportional to the thickness of the film. It may be seen, therefore, that the flow of a gaseous medium by work being heated should be as uniform as possible. If the velocity of gases differs radically at various points in a kiln, the thickness of the film surrounding the work will vary with resultant variations in the rate of heat transfer.

Flow of gases through a work chamber should be of uniform velocity in order that the quantity of heat as well as the temperature distribution will be unvarying. It is obvious that if the volumes of gases passing two pieces of work differ, the amount of heat available for transmission to the work will not be the same, irrespective of initial temperature uniformity.

The designer is, therefore, confronted in direct firing of ceramic ware, where convection is to be the principal heat-transfer factor, with the problem of temperature and flue-gas volume control or, as we have termed it, heat distribution.

It is well to emphasize again that in combustion of fuels heat which is liberated may be dissipated from the zones of combustion reaction by convection, radiation, and conduction. Under most conditions, dissipation by convection of flue gases is the major factor. With incandescent coal beds, high-intensity oil combustion, or diffusion gas flames, the radiation component may, however, be considerable. In fact, radiation from a gas flame resulting from combustion of a theoretical air-gas mixture is greater than is ordinarily thought to be. The heat in flue gases may also be converted in part to radiant heat by heating a bed of refractory kiln furniture or, more generally, the walls and roofs of the kiln, which in turn re-

radiate energy. Thus it should be apparent that if heating by radiation is desired it can be done with combustion of fuels.

(3) Flue-Gas Temperatures

Flue-gas temperatures adjacent to combustion zones, while depending on many variables and subject to some control, are, generally speaking, appreciably higher than that required by ceramic processes. Common practice has followed several methods in reducing these temperatures; *e.g.*, large volumes of secondary air will accomplish this purpose but at the expense of economy. Similarly, dissipation of heat through combustion or work-chamber walls will serve to reduce flue-gas temperatures, but again economy will be impaired. Progressive combustion has also been employed but, as previously discussed, precise atmosphere control is difficult, if not impossible, under such conditions. The most feasible method of accomplishing this purpose is the abstraction of heat from the flue gases by refractory surfaces, which becoming incandescent will re-radiate heat to flue gases, after they have given up a portion of their heat, and to the work itself. Such a conversion of energy reduces the initial temperature of the circulating flue gases, serves to compensate for the abstraction of heat from the flue gases by work and furnace walls, and accomplishes these tasks with high efficiency. In other words, with this principle, uniformity of heat distribution by direct firing with convected heat becomes practical.

In applying it, we must first have a fuel and combustion method whereby heat can be abstracted from the flue gases adjacent to the combustion zone without interfering with the combustion reaction or the composition of the flue gases. Otherwise, neither efficient combustion nor close atmosphere control could be secured. When the amount of air required for complete combustion of gas is supplied prior to the combustion zone, it furnishes the means for accomplishing the desired end. Combustion of practically any amount of gas, from a few thousand to millions of B.t.u. per cubic foot of combustion space, can be completed within a compact, well-defined zone. From this point on through the kiln, abstraction of heat from, direction of, and interference with the flue gases for purposes of adjusting heat distribution will exert no effect on their composition or the completeness of combustion.

Completely burned flue gases emitted in a work chamber immediately begin to give up heat, which is, of course, their function. These losses may be compensated for through absorption by the flue gases of radiant energy. However, where flue gases enter the work chamber from a very limited area or, at the most, from a few points, the difficulties of striking a balance between heat losses from and absorption by flue gases are obviously enormous. If such a balance is not secured, a temperature gradient through the kiln must exist. Thus, the advantage of liberating heat or rather of admitting flue gases to a work chamber from as large a number of points and as in many different locations as desired constitutes a distinct and valuable advantage.

VII. Use of Large Number of Burners

From the researches carried on at our Laboratory, the employment of a large number of burners will also provide lower flue-gas temperatures for equal heat liberations. Larger quantities of gas, moreover, can be burned per cubic foot of combustion space. Incidentally, it has been possible during our investigations to burn completely nearly 9,000,000 B.t.u. of gas per cubic foot of combustion space. By utilizing high combustion rates, a multitude of burners can be employed without unduly enlarging combustion spaces or adding to the bulk of a kiln. Premix burners, in which the flow of mixture is turbulent, will also afford lower flue-gas temperatures and permit combustion of greater quantities of gas than a burner with a streamlined approach. Other advantages of streamline burners, however, such as quietness of operation, might offset these attributes.

VIII. Types of Burners

Comparisons of different types of burners and other equipment will not be given since the reports are listed at the end of this paper. Much commercial gas equipment, while of complex nature, is designed to perform specific functions which could not be efficiently and precisely accomplished by other less complex means.

IX. Conclusion

Maintenance of uniform heat distribution and predetermined atmospheres constitute important objectives of direct firing of ceramic ware. Other

time-proved methods have produced desirable conditions, generally by employing saggers for tempering uneven primary heating mediums and mitigating unsatisfactory atmosphere conditions. The net load or ware in a kiln, with these other methods, often constitutes a small percentage of the total mass to be heated. The economic loss is, therefore, great. Fuel savings possible with direct firing have long been recognized, but considerations of heat distribution and atmosphere have been obstacles. Recent developments have demonstrated the practicability and desirability of employing gas for direct firing of both glost and bisque ware.

List of Bulletins

The American Gas Association Testing Laboratory bulletins on investigations for the Committee on Industrial Gas Research are given as follows:

Report No. 685. A study of the characteristics of burning gas with preheated air.
Report No. 692. Research in the elimination of noise in industrial gas burners; Report No. 724. (2nd *Bull.*)
Report No. 694. Standard nomenclature for industrial gas combustion systems.
Report No. 723. Research in the fundamentals of combustion space requirements in high-temperature gas furnaces.
Report No. 746. Research in the effect of operating temperature on the combustion of industrial gas; Report No. 748. (2nd *Bull.*)

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EDITORIALS

THE GLASSY PHASE IN THE MANUFACTURE AND USE OF REFRACTORIES*

By George W. Morey

Abstract

The material which appears as glass when a refractory is cooled is manifestly a liquid at high temperatures and as such plays an important part in the manufacture and destruction of refractories. Because of the inherent viscosity of silicate liquids, it may be a source of strength at temperatures below the true melting point, a property which gives the silicate refractories their wide range of usefulness. Glass appears early in the firing of a clay and plays a dual rôle. On the one hand, it serves as a bond. On the other hand, it is a corrosive liquid which promotes reaction between the components of the refractory, at lower temperatures increasing the density and strength, while at higher temperatures it causes the destruction of the refractory. When used for the manufacture of glass, the life of the refractory depends in large measure on the rate of mixing of the more viscous glass which is part of the refractory with the more fluid glass being melted.

I. Introduction

When a fired refractory is examined under the microscope some quantity of glassy material is always found, and when the refractory has been in service, especially at temperatures approaching its limit, the quantity of glass is greatly increased. The material which is found as glass at ordinary temperatures, however, is not glass at high temperatures. The extreme viscosity which causes the glass to have a high rigidity at ordinary temperature is lost as the temperature is increased, and at the working temperature the glass may have become a corrosive liquid. The correlation between the properties of this glass and those of the refractory itself can be made on the basis of our knowledge of the chemical relationships of silicate systems, and such a correlation is of value in explaining the reasons for the superior or inferior behavior of refractories of different compositions under different conditions of service and in suggesting improvements in refractory composition. In general, however, the conditions of equilibrium are rarely approached, and the equilibrium relationships point out the goal toward which the various chemical reactions are striving, with rates determined by other, usually unknown, factors.

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While the material found as glass at ordinary temperatures is a manifest liquid at high temperatures, the properties which make it possible for it to be cooled as a glass are of great importance in its relations at high temperatures. The fundamental property characteristic of glass is that it can be cooled through its freezing point without crystallizing, and the reason is that at the freezing point its viscosity is so very great. But this quality of possessing a high viscosity at high temperatures at which most other compositions of matter form liquids of great fluidity is the outstanding characteristic of silicates. Compositions which melt to liquids of high fluidity can be of value as refractories only below temperatures at which liquid can form, that is, below the melting point of the lowest melting compound or eutectic capable of being formed from the components. But because of the great viscosity of silicate liquids, both below and above the liquidus temperature, their presence in the refractory not only does not ruin the material but may even be beneficial.

II. Manufacture of Refractories

The discussion of the manufacture of refractories will be confined to those whose character is dominated by the presence of silica, a restriction which only excludes from consideration a small proportion of the refractories which are manufactured. Most refractories are made from clay or a mixture of one or more types of clay with other and more refractory constituents, with which it is hoped the clay will react and form a bond. Let us first consider what happens when clay is fired.

(1) Decomposition of Clay Minerals

Clays are usually mixtures of several compounds of alumina, silica, and water,[1] of which kaolinite, $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$, is typical. When kaolinite is heated, the water is driven off, with decomposition of the kaolinite. Consider this reaction in detail.

The decomposition of a salt hydrate is well understood. At every temperature there is a definite dissociation pressure characteristic of the dissociation reaction. At every temperature the dissociation pressure is fixed, a function of the temperature. There is no one "decomposition temperature," and decomposition may or may not be complete before the dissociation pressure reaches one atmosphere. That is determined either by the crystalline phase, which is losing water, reaching an incongruent or a congruent melting point at which the dissociation pressure curve terminates, or by the removal of the gaseous product of dissociation, causing the reaction to go to completion.

The dissociation pressure is characteristic of the reaction in its entirety. One commonly speaks of the dissociation pressure of $CuSO_4 \cdot 5H_2O$; but the pressure is characteristic of the reaction

$$CuSO_4 \cdot 5H_2O = CuSO_4 \cdot 3H_2O + 2H_2O$$

and is only defined when all three phases are specified. If the dissociation should skip the three-hydrate, and the penta-hydrate dissociate directly to the mono-hydrate, a type of thing which does happen, the dissociation pressure would be entirely different. Moreover, even though the reaction can be defined in terms of the phases which are present, the measurement of real values is difficult even in favorable cases. To obtain values of the equilibrium pressure (the only pressure which has any meaning), it is necessary that the reaction be actually reversible in the experiment itself. That is well known. But when compounds such as the clay minerals or zeolites are under consideration such elementary matters are usually forgotten. Measurements in the literature of the "temperature of decomposition" of kaolin are not in agreement because they are intrinsically meaningless. Measurements of vapor pressure are frequently made, usually with results differing from previous observers. The lack of agreement is due not only to the failure to deal with a single pure substance, a failure which is particularly evident since the work of Ross and Kerr,[1] but also to the failure to carry out the reaction under reversible conditions.

(2) Reversibility of Reactions

The difficulty is, of course, to find conditions under which the reaction is reversible. What the nonvolatile product or products of dissociation of kaolin are is uncertain. It may be metakaolin, as believed by many investigators, including Hyslop and Rooksby.[2] They studied the de-

[1] C. S. Ross and P. F. Kerr, *U. S. Geol. Surv. Prof. Paper*, No. 165, pp. 155–71 (1931). See also C. S. Ross and P. F. Kerr, "Kaolin Minerals," *Jour. Amer. Ceram. Soc.*, **13** [3] 151–60 (1930); "The Clay Minerals," *ibid.*, **16** [1] 51–58 (1933).

[2] J. F. Hyslop and H. P. Rooksby, *Trans. Ceram. Soc.* [Eng.] **27**, 93 (1928).

composition by X-rays and believed they had evidence of the formation of a new compound which might be metakaolin. But their evidence is not conclusive and is in conflict with the X-ray study by Rinne.[3] The product of dissociation may be an amorphous mixture of alumina and silica, a glass. That mixture would not correspond to equilibrium. The equilibrium products might be quartz and mullite, quartz and sillimanite, andalusite, or kyanite, but all of these are equally unattainable even on long-continued heating, much less under ordinary conditions of firing. But no matter which interpretation is correct, the decomposition reaction is irreversible. That is not to say that under some other conditions, such as at elevated temperature and under high pressure of water, kaolinite may not be possible of synthesis, but under the conditions prevailing in the studies which have been made of the dissociation of kaolin and under the conditions met with in practice, the reaction is not reversible in fact. The results obtained represent rates of reaction under poorly defined or undefinable conditions, and deductions drawn from them, such as heats of reactions, still more, heats of activation, are worthless and misleading.

(3) Glass Is a Bond

Glass, then, appears at an early stage in the firing of refractories, since the dehydration of kaolin, under ordinary conditions, is largely complete at 650°C. The glass, of course, is unstable and, especially as the temperature is raised, tends to precipitate out the stable phases, which are mullite and some form of silica, depending on the temperature. Because of the extreme viscosity, crystallization is slow, and under ordinary conditions of firing not much takes place. Rather, the refractory owes its strength to the inherent viscosity of the glass, which serves as a glue to bind the grog.

(4) Glass Is a Solvent

While the liquid is unstable in respect to its own products of devitrification, except at the highest temperatures, it also is a solvent for everything with which it may come into contact. Some of the materials which it may dissolve will greatly diminish its viscosity: lime, magnesia, and iron oxide belong in this class. Others have little effect, notably silica and alumina. While the rate of reaction of the glass with the grog is small, that reaction is of the highest importance in obtaining a resistant body. No one doubts that reaction can take place between solids in contact, but there must be a common interface for reaction to occur. If no liquid phase is present, reaction in silicate mixtures will be much slower than when liquid is present. Under the conditions of firing, reaction takes place between liquid and grog and bonds the mass together in a firm, dense structure, able to resist stress. The rate of this reaction is small and even after the refractory has been some time in service a large amount of unaltered material is still present.

(5) Composition of the Grog

The rate of alteration depends also on the composition of the grog. If it has substantially the composition of the clay mixture, similar reactions take place within it, and the mass as a whole develops a structure of interlocking mullite needles and viscous siliceous glass. If quartz is incorporated in the body, it is slowly dissolved by the liquid, and the residual quartz is transformed into tridymite or cristobalite. This transformation is slow, and unaltered quartz cores are often found in used refractories. At the interface between liquid and crystal, however, there is found a zone of needle crystals, usually cristobalite, which have separated from the saturated solution. Here the liquid plays its usual dual rôle of providing an interface to accelerate the reaction and of transporting away from the interface the dissolved material, thus increasing the rate of solution.

When the grog is a highly aluminous material, the reactions which take place are more complex. Solution takes place, usually with separation of needles of mullite. The interlocking network built up by the mullite needles contributes in large measure to the strength of the refractory. They usually grow at the interface between the liquid and the grog, and complete solution and transformation may take place. Such complete reaction is rarely the result of the firing, but only of long-continued service, and in service other factors usually terminate the useful life of the refractory before the conversion to mullite is complete.

(6) Summary

The entire history of the firing of a refractory

[3] F. Rinne, *Z. Krist.*, **61**, 113 (1925).

and its life in service is one in which the liquid, which cools to a glass, plays a dominant rôle. The bonding of the heterogeneous material into a strong, dense mass capable of bearing a load is directly the function of the liquid. The reactions which take place between the various constituents do so through the medium of a liquid which, in spite of its high viscosity, makes possible the transport of the materials which it takes into solution. And the great viscosity of the silicate liquid makes possible the use of siliceous refractories at temperatures at which liquid is present, thus giving them that useful temperature range which is their distinctive characteristic.

III. Refractories and Glass

The refractories used in the manufacture of glass are subjected to a continuous corrosion, the rate of which determines their life. There is no possibility of an equilibrium, because the materials of which the refractories are composed are all soluble in the glass and enter into its composition as actual constituents. The problem confronting the glassmaker is one of reducing the rate of solution to a minimum when the containers are continuously subjected to the corrosive action of the glass. Petrographic examination of the interface between refractory and glass furnishes the only clues as to the factors which can be changed to diminish this rate of solution.

(1) Reactions at the Interface

The interface between glass and refractory usually is a thin, sharply delimited white layer, composed largely of a network of needles of mullite, with interstitial highly aluminous glass. The solvent action of the glass has extracted from the refractory the excess alumina, with formation of new mullite crystals. This represents a decomposition process, with the layer of glass next to the refractory increasing its alumina content until it becomes saturated with mullite and, by virtue of that saturation, solution of mullite becomes much less rapid. But the glass is not saturated with alumina. It still retains the power to dissolve alumina from any source other than that crystalline phase with which it is saturated, and the dissolved alumina will tend to separate as new mullite crystals. The mullite layer does not serve as a thermodynamic protection, but only as a mechanical one.

The glass containing the highest percentage of alumina is that embedded in the white layer and immediately between it and the mass of the refractory. It is here that the solvent action of the glass is most active, but to get here the glass must diffuse or penetrate through the mullite layer. It is sometimes assumed that this results in a concentration of the more mobile constituents of the glass, the alkalis, in the region next to the refractory, thereby increasing the possibilities of corrosion. This hypothesis is not a probable one. The mesh of mullite crystals with interstices filled with a glass differing from the rest of the glass only in a higher alumina content can not be regarded as a semipermeable membrane, and there is no evidence that selective adsorption takes place. To assume that a concentration of alkali takes place by virtue of different diffusion rates is actually to attempt to set up a mechanism for the spontaneous separation of homogeneous solutions into their component parts, a process which is improbable and in conflict with experience.

(2) Rate of Attack on Highly Siliceous Refractories

The rate of attack at the interface depends on the material being dissolved, whether it is the interstitial glass formed within the refractory itself or mullite or corundum forming part of the original batch. The rate of solution of the glass, or rather, the rate at which the interstitial liquid originally in the refractory mixes with that coming from the glass being melted, depends on many factors, important among which is the original purity of the clays. Most of the impurities, alkali oxide, lime, magnesia, and iron oxide, accumulate in the glass and each of them tends in varying degree to increase the fluidity and hence the rate of interdiffusion of the two liquids. In the worst of cases, however, the glass within the refractory greatly exceeds in viscosity that being melted, and the greater this difference the longer the life of the refractory. It is partly for this reason that high silica refractories often hold up a surprisingly long time under conditions which cause them to contain a large proportion of glass. The glass is so viscous that diffusion into it is slow. Moreover, the composition gradient near the interface is not so great with a highly siliceous glass as would be the case with a highly aluminous refractory. The difference in chemical potential, the driving force of the reaction, is less, and this factor may play an important part in the use of

highly siliceous refractories. When coarse mullite grains are being dissolved the rate of solution is slow, and is even slower when corundum is the grog. In either case, the coarser and denser the structure of the grog the less rapid is its rate of solution, and a refractory often fails because of extensive pitting which causes pieces of refractory containing unaltered grog to slough off.

(3) Rate of Attack on Highly Aluminous Refractories

The mullite needles in the white layer next to glass are readily soluble in the glass and are constantly being renewed by precipitation. Conditions at this interface vary and are especially sensitive to the action of currents in the glass. These may be part of the general convective flow in the tank, or they may be caused by local density differences, causing the glass containing the dissolved material either to rise or sink along the walls. If this process is rapid the refractory will have a short life. Usually the convection is not great enough to renew the viscous layer of glass next to the white line, and this layer itself may show interesting features.

Frequently corundum is formed, representing the product of decomposition of the mullite by the glass. It is a new crystallization, however, and its presence is not easy to explain. It is probable that it is caused by the displacement of the decomposition of mullite to corundum to lower temperature in contact with the liquid. It is known that in the ternary system, Na_2O–Al_2O_3–SiO_2, the boundary between corundum and mullite is displaced to lower temperatures and higher silica content as the alkali content is increased, and it is probable that the same effect even to a greater extent will be found in the four-component system formed by the addition of lime, which would correspond to the liquid in contact with refractory in the case of a soda-lime glass.

The occasional formation of carnegieite or nephelite is easier to explain. $Na_2O{\cdot}Al_2O_3{\cdot}2SiO_2$, in its two forms, carnegieite and nephelite, occupies a large field in the ternary system, Na_2O–Al_2O_3–SiO_2, and it is not surprising that when a glass containing Na_2O and SiO_2 dissolves a large amount of Al_2O_3 the solubility limit of nephelite should be reached.

The formation of feldspar is not so common, not because the melt does not contain the necessary ingredients, but because the soda feldspar, albite, has a melting point lower than ordinary tank temperatures. But albite is one end member of the plagioclase feldspar series of solid solutions, the other end member of which is the lime feldspar, anorthite, which has a melting point of 1550°. Albite is a poor crystallizer, but the lime-rich feldspars crystallize readily, and conditions frequently are such that one of the plagioclase series, labradorite, is formed. But both nephelite and labradorite dissolve readily in the glass, and compositions favorable for their formation are found only in the aluminous layer outside of, and adjacent to, the white layer, so that they are continually being dissolved and are not often found as stones. Only when a melt is cooled is there opportunity to find them, and they are often found on cooled tank blocks. In all of these cases, however, the dominant factor is not the equilibrium relations in the system, but the rates of solution of refractory, of precipitation of compounds whose solubility limits are exceeded, and of subsequent solution of those compounds which have crystallized.

Geophysical Laboratory
Carnegie Institution of Washington
Washington, D. C.

"BORA"

By S. R. Scholes

As a matter of convenience, brevity, and consistency with chemical nomenclature for other oxides, B_2O_3 should be called "bora." Its name has improved from "boron trioxide" (when we knew no di- nor mono- form) to "boric oxide" (which is in common use, although there is no borous oxide) and finally to "boron oxide."

This last is exact, but it is also as unnecessarily long and descriptive as "silicon oxide," or "aluminum oxide," in comparison with their standard names. No one can urge "plumba," or "zinca," on grounds of euphony or accuracy; but virtually every ceramic oxide, where the element has only one usual valence, has a name ending in "a."

"Bora" is nominated; and let no punster prate of politics, pests, or punctures!

N. Y. State College of Ceramics
Alfred, N. Y.

ACTIVITIES OF THE SOCIETY

MEMBERSHIP

AN INCREASE—EIGHTY THREE* IN ONE MONTH OF PAID MEMBERS AND SUBSCRIBERS

* Twenty-seven of these were Personal and two were Corporations not heretofore members.

	PERSONAL		CORPORATION	
	Apr. 15	May 20	Apr. 15	May 20
Paid in full	1069	1130	171	178
Deferred	84	79		
Part-payment	56	50		
Honorary, Life, and Complimentary	29	29		
Subscribers	383	409		
Advertisers			31	31
	1621	1697	202	209
Current Sales			200	200
Total Circulation			2023	2106

It rests with you what the June Record shall be.

THE BULLETIN $1.50 A YEAR

THE BULLETIN is one means of introducing the Society to your associates. How many subscriptions will you sell? Subscription price $1.50 a year.

ADVERTISING—will you tell your material and equipment suppliers that you expect to see their advertisement in *The Bulletin?*

THE BULLETIN—OUR CONTACT MEDIUM

The Bulletin is one of the Society's most valuable means of contacting prospective members for the American Ceramic Society. Its nominal yearly subscription cost is $1.50. For this small sum the American Ceramic Society can be introduced to many who are not now members.

The worth of the Society to its members is constantly demonstrated. Through *The Bulletin*, nonmember ceramists who need the services of the Society may be introduced to the many valuable helps the Society offers.

Will you provide this introduction? As the membership in the American Ceramic Society grows, so grows its value to you. With increased membership, come lower service costs and an increase in the services it can offer you.

Testimony:—Twice this month men prominent because of their success as ceramists have, on their own initiative, told us that without the American Ceramic Society they could not have achieved and accomplished as much as they have. Their debt to the Society they acknowledge. Will you so testify?

OUR SUMMER MEETINGS

Art Division: October 25 to 27, 1935. Annual Robineau Memorial Ceramic Exhibition, Syracuse, N. Y.

Glass Division: September, 1935. Lake Keuka, New York.

Refractories Division: September 20 to 22, 1935. Penn State College, State College, Pa.

White Wares Division: September 5 to 8, 1935. New Brunswick and Beach Haven, N. J.

OUR 1936 ANNUAL MEETING

Only forty-one weeks, less than ten months, remain in which to prepare the programs for the 1936 Annual Meeting which will be held in Columbus, Ohio, March 29 to April 4, 1936.

What will these programs be? We can ill afford to procrastinate in making plans for this Meeting.

NEW MEMBERS

Corporation

National Engineering Co., L. B. Knight, Jr. (voter), 549 W. Washington Blvd., Chicago, Ill.

Personal

Balph, Rowland P., 1513 Rockefeller Bldg., Cleveland, Ohio; district sales manager, Harbison-Walker Refractories Co.

Blake, William V., 527 Lansing Ave., Jackson, Mich.; ceramic engineer, Macklin Co.

Campbell, G. Donald, 327 Rosemont Ave., Clarksburg, W. Va.; chemical engineer, Pittsburgh Plate Glass Co.

Clawson, C. D., Caixa Postal 2814, Alameda Glette 61, Sao Paulo, Brazil; manager, Brazil office, Ferro Enamel Corp.

Davidson, Thomas R., 5th St., Carrollton, Ohio; superintendent, The Carrollton China Co.

Douda, Henry, The Royal China Co., Sebring, Ohio; superintendent.

Durbin, Edmund A., Ceramic Division, Champion Spark Plug Co., Detroit, Mich.; ceramic engineer.

Gregorius, T. K., 1120 Highland St., Tarentum, Pa.; assistant superintendent, Pittsburgh Plate Glass Co.

Hannegan, Michael H., 201 E. Chestnut St., Mt. Vernon, Ohio; plant chemist, Pittsburgh Plate Glass Co.

Lane, Richard O., 367 Thompson Ave., East Haven, Conn.; foreman, Wire Rope Dept., American Steel & Wire Co.

Smith, F. E., Harris Clay Co., Spruce Pine, N. C.

Steinbock, E. A., Whipmix Corp., 422 W. Avery St., Louisville, Ky.

Thurnauer, Hans, 190 N. Crest Road, Chattanooga, Tenn.; development engineer, American Lava Co.

Wampler, Roy W., Libbey-Owens-Ford Glass Co., Toledo, Ohio; research chemist.

Wiedemann, H. E., 1604 Chemical Bldg., St. Louis, Mo.; consulting chemist.

Wright, Daniel K., Incandescent Lamp Dept., General Electric Co., Nela Park, Cleveland, Ohio; engineer, Lamp Development Laboratory.

Wurtsbaugh, Clarence G., 8624 San Juan St., Southgate, Calif.; ceramist, T. S. Curtis Industrial Research Laboratory.

Student

Condon, Alfred B., Pennsylvania State College.

Kamper, Oliver, Missouri School of Mines.

Madden, Robert C., Massachusetts Institute of Technology.

McDonald, C. H., Missouri School of Mines.

Springer, Robert M., Missouri School of Mines.

Tarnopol, Milton S., Massachusetts Institute of Technology.

Membership Workers' Record

Corporation

C. E. Bales	1

Personal

R. M. Bowman	1	C. H. Peddrick, Jr.	1
George Brian	1	V. J. Roehm	1
T. S. Curtis	1	C. D. Spencer	1
J. S. Gregorius	3	F. J. Stevens	1
J. E. Hansen	1	L. G. Tait	1
L. C. Hewitt	1	A. S. Watts	1
H. M. Kraner	1	Office	2
		Total	17

Student

C. M. Dodd	3	N. W. Taylor	1
F. H. Norton	2		
		Grand Total	24

ROSTER CHANGES DURING MAY

Corporation

Orton, Edward, Jr., Ceramic Foundation, George A. Bole, (voter), 1445 Summit St., Columbus, Ohio. (Standard Pyrometric Cone Co.)

Pacific Clay Products, Robert Linton (voter), Box 145, Sta. A, Los Angeles, Calif. (650 Chamber of Commerce Bldg.)

Wheeling Steel Corp., W. F. Copp (voter), Portsmouth, Ohio. (T. W. Jenkins, voter.)

Personal

Alcan, Raphael F., 27 Elm Ave., Metuchen, N. J. (Maurer, N. J.)

Allison, Adrian G., Charles Taylor Sons Co., P. O. Box 58, Annex Sta., Cincinnati, Ohio. (Columbus, Ohio.)

Bassett, Robert B., Fiske Brick & Granule Co., Darlington, Beaver County, Pa. (Milton, Pa.)

Biggs, Henry C., 245 Byron Road, Wealdstone, Middlesex, England. (Bonnybridge, Scotland.)

Cibella, Ross C., 3365 E. 135th St., Cleveland, Ohio. (2652 E. 45th St.)

Delangre, Maurice, 8 Avenue du General Horne, Valenciennes (Nord), France. (Georges Delangre.)

Fraulini, Felix, Missouri Training School for Boys, Boonville, Mo. (Bevier, Mo.)

Gibson, Frank G., 57 Olentangy St., Columbus, Ohio. (Santa Marta Rep. at Colombia, South America.)

Gould, Robert E., Tennessee Valley Authority, Norris, Tenn. (Katowice, Poland.)

Hill, E. C., Abrasive Co., Bridesburg, Pa. (Conkling-Armstrong Terra Cotta Co., Philadelphia, Pa.)

Latimer, Horace L., 1925 Mallory, Flint, Mich. (313 W. Court St.)

Loomis, George A., Ohio Valley Clay Co., Steubenville, Ohio. (Engineering Experiment Sta., Columbus, Ohio.)

Malsch, Werner, 402 6th Ave., Belmar, N. J. (Miami Beach, Fla.)

Manson, M. E., Underwood Hotel, Wauwatosa, Wis. (Lake Bluff, Ill.)

McGean, Ralph L., McGean Chemical Co., 1106 Medical Arts Bldg., Cleveland, Ohio. (1030 Keith Bldg.)

Palmer, Willard E., Box 663, Fisher Ave., East Liverpool, Ohio. (Chester, W. Va.)

Parsons, Joseph R., Wellsville Fire Brick Co., Wellsville, Mo. (Chicago Fire Brick Co., Chicago, Ill.)

Sommerville, James L., Owens-Illinois Glass Co., Alton, Ill. (Winburne, Pa.)

Strong, Kenneth B., James Court, Mundelein, Ill. (Owosso, Mich.)

Tefft, C. Forrest, The Claycraft Co., P. O. Box 866, Columbus, Ohio. (P. O. Box 496.)

Thornton, Paul E., 116 Paddock St., Crystal Lake, Ill. (20 N. Caroline St.)

Young, Willard G., 206 Jefferson St., Robinson, Ill. (401 W. Walnut St.)

Zopfi, Albert S., 1143 River Road, Maumee, Ohio. (Toledo, Ohio.)

FORTY YEARS OF CERAMIC EDUCATION

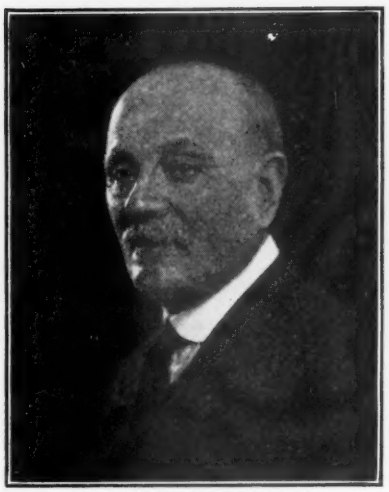
In May, 1894, the State of Ohio by legislative act, provided for a Department of Ceramic Engineering at Ohio State University.

This was the first department of its kind in the world—the first great gift to American ceramics made by Edward Orton, Jr.

The American Ceramic Society and The Edward Orton, Jr., Ceramic Foundation are two other gifts made by Orton to American ceramics.

NECROLOGY

Bernard Moore



BERNARD MOORE

Bernard Moore, aged eighty-five, who was elected to Honorary Membership in the American Ceramic Society in February, 1935, passed away on April 3, 1935, at his home at Stoke-on-Trent, England, before word of this honor reached him. Bernard J. Moore, his son, has written that his father died after only a short illness. "I am sure that he would very much have appreciated the honour you conferred upon him in making him an Honorary Member of The American Ceramic Society. An honour so conferred at least will afford an appreciation of the great man, my father, who is lost to the ceramic industry. Please convey my very best thanks on behalf of the family to the Society."

Bernard Moore was a potter of world-wide reputation. He successfully reproduced the glazes of the old Chinese craftsmen. His specialty was the production of *sang-de-boeuf*, *rouge flambé*, and *gold flambé* ware, which were acclaimed by experts as even more brilliant than the productions of the old Chinese dynasties.

For many years, Mr. Moore had showrooms and a works in Stoke, where he practiced as a consultant potter. Potters and art connoisseurs from all parts of the world visited his premises, and his productions are in many museums, including the British and South Kensington Museums and the executive offices of The American Ceramic Society. Mr. Moore was a past-president of the English Ceramic Society for many years, and also prominent in research work in the pottery industry.

EDITOR'S NOTE: We are indebted to H. Greville Montgomery, editor of *The British Clayworker* for the use of the accompanying cut of Mr. Moore and also for information concerning his work.

William A. Collings

William A. Collings, Santa Monica, Calif., died early this year according to word which has been sent to the Society. He joined the Society in 1924 and became an active member in 1926.

HINDU UNIVERSITY SENDS EXHIBIT OF PORCELAIN TOYS

Shipped in October, 1934, from Benares Hindu University ten porcelain toys, seven of the pieces glazed and three of them bisque, arrived in the offices of The American Ceramic Society, Columbus, Ohio, the last of March, 1935.

Well packed, the pieces easily survived the ocean trip but encountered numerous difficulties once they were landed in New York.

The parcel was taken from the ship immediately to storage because no representative of the Society was present to claim the toys. There they would have been kept until sold for the storage charges if both sender and addressee had not begun a search to locate the undelivered package.

The insurance papers on this box were forwarded from India by S. Dogar Singh, the sender, and, with information from these, the consignment was finally located in the New York warehouse.

After the package was located it was necessary to employ a local Customs House broker, who, acting through an agent in Chicago, had the box shipped to Columbus.

Upon arrival in Columbus the toys were by no means out of danger. The U. S. Customs inspector, upon opening the box at the station, found the pieces packed in straw. Straw from foreign places is not allowed here, so with proper forms secured from the consignee the straw and box from India were burned.

Carelessly repacked by an agent, the pieces were brought to the offices of the Society.

The difficulty encountered in effecting the delivery of these toys has added to their interest as an unusual foreign exhibit.

Deities and native animals, including the sacred cow, a lion, tiger, and elephant, as well as a fish brilliantly glazed in pink, blue, and green are shown in the cover illustration.

President J. M. McKinley, visiting the office soon after the exhibit was set up, liked the work so well that he made several photographs of the toys.

Invitation to Send Exhibits

It is hoped that other Ceramic Departments, both in this country and abroad, will find it possible to send representative pieces of their work for display in the offices of the oldest ceramic society in the world.

Such exhibits will be most welcome.

LOCAL COMMITTEES FOR 1936 ANNUAL MEETING ORGANIZED

The Executive Committee for the Annual Meeting of The American Ceramic Society, to be held in Columbus Ohio, March 29 to April 4, 1936, has been named. The members are as follows:

George A. Bole, Manager, Edward Orton, Jr., Ceramic Foundation, 1445 Summit St., Columbus, Ohio.

Clyde E. Williams, Battelle Memorial Institute, Columbus, Ohio.

C. Forrest Tefft, P. O. Box 866, Columbus, Ohio.

Earl Crooks, Crooksville China Co., Crooksville, Ohio.

Frank Ransbottom, Robinson-Ransbottom Pottery Co., Roseville, Ohio.

Arthur S. Watts, Lord Hall, Ohio State Univ., Columbus, Ohio.

Walter Rueckel, Engineering Expt. Sta., Ohio State Univ.

The Committee Chairmen appointed by the Executive Committee are named below. These chairmen will select the personnel of their committee.

Meeting Service: John D. Sullivan, Battelle Memorial Institute.

Entertainment: Ross C. Purdy, 2525 N. High St.

Ladies' Entertainment: Mrs. Ellsworth P. Ogden, 1957 Chelsea Road.

Plant Trips: J. L. Carruthers, Lord Hall, Ohio State Univ.

Publicity: Clyde E. Williams, Battelle Memorial Institute.

Exhibits: Arthur S. Watts, Lord Hall, Ohio State Univ.

Finances: C. Forrest Tefft, P. O. Box 866.

	Saturday Mar. 28	Sunday Mar. 29		Monday Mar. 30		Tuesday Mar. 31		Wednesday Apr. 1		Thursday Apr. 2	Friday Apr. 3	Saturday Apr. 4
	All day	All day	Night	All day	Night	All day	Night	All day	Night	All day		
Trustees	Wallick Suite		President's Reception—Concert—Deshler Ball—8:00	Wallick Suite	General Meetings—Deshler Ball	Wallick Suite	Edward Orton, Jr., Lecture—9:00—Deshler Ball	Wallick Suite	Dance—Floor Show—Neil Ball	Wallick Suite	Extra Division Sessions—Tour of Columbus Claycraft—Enamel—and Glass Factories Ohio State University—Battelle—Orton Lab.	
Trustees and Committees		Deshler A. B. C.			Supper—Entertainment—7:30—Deshler Ball							
Art Division						Neil Blue		Neil Blue				Zanesville Roseville Crooksville
Enamel Division						Deshler A. B. C.		Deshler A. B. C.				Newark
Glass Division						Neil Ball		Neil Ball				Newark Lancaster
Materials and Equipment												
Refractories						Deshler Ball		Deshler Ball				
Structural Clay						Neil Red		Neil Red				Claycraft New Lexington New Straitsville
Terra Cotta						Neil Garden		Neil Garden				
White Wares						Neil Jr. Ball		Neil Jr. Ball				Zanesville Crooksville
Registration		← Deshler Assembly Room →				← Neil Mezzanine →						
Publicity and Editorial		← Room 21 Deshler →				← Neil Mezzanine →						

LOCAL SECTION NEWS

CENTRAL OHIO SECTION MEETS

R. B. Sosman, Research Laboratory, United States Steel Corp., Kearny, N. J., was speaker at the meeting of the Central Ohio Section held May 24 at Columbus, Ohio. His topic was "The Why of Steel Making Refractories."

Dr. Sosman divided refractories for steel melting into those used in the melting chamber and those necessary for handling the steel after it is poured from the melting chamber.

In the steel melting chamber a refractory must meet three problems, (1) fusion of the steel, (2) oxidation of the impurities, and (3) mechanical strains. In the old Bessemer process a siliceous lining gave very good results

until phosphorus and sulfur-bearing materials were used. These made the process unsatisfactory since these impurities must be removed by a base.

For this reason, the basic magnesite lining has come into almost universal use today.

The reactions involved in the slag from impurities in the metal were also discussed. Dr. Sosman pointed out that a study of the MnO–FeO–SiO_2 system offers a fertile field for valuable research work.

An interesting discussion of the cause of failure of an open-hearth roof when the furnace atmosphere was changed from oxidizing to reducing followed Dr. Sosman's paper.

—CHESTER R. AUSTIN, *Secretary*

J. P. SMYTH AND R. B. SCHMITT SPEAK AT BALTIMORE

The Baltimore-Washington Local Section met in Baltimore, Md., May 11. During the afternoon members and their guests inspected the rare collection of ceramic pieces in Walter's Art Gallery in Baltimore. Examples of the ceramic art of the Chinese, Egyptians, and the old European masters were displayed.

Forty-one members and guests attended the dinner.

J. P. Smyth talked of "Art and Ceramics from a Collector's Viewpoint." Mr. Smyth, a collector and connoisseur of the ceramic arts, discussed the influence of early Chinese works of art on present-day design. He stressed the need and economic desirability of color in ceramic products.

Richard B. Schmitt, S. J., of Loyola College, Baltimore, spoke on "Micro-Analytical Methods and Their Possible Uses in Ceramics." Father Schmitt is a specialist in micro-analytical work and is in charge of one of the most completely equipped microchemical laboratories in the country.

He described the current trends in chemistry of small quantities with particular emphasis on practicability and accuracy. The timely and excellent talk was well illustrated with slides.

The following officers of the Local Section were elected for 1935–1936: *Chairman*, Roy G. Blunt, Baltimore; *Vice-Chairman*, S. M. Shelton, Washington; *Secretary-Treasurer*, G. H. Spencer-Strong, Baltimore; and *Councillor*, T. A. Klinefelter, Washington.—S. M. SHELTON, *Secretary-Treasurer*, 1934–1935.

MICHIGAN-NORTHWESTERN OHIO SECTION MEETS

A joint meeting of the Michigan-Northwestern Ohio Section of the American Ceramic Society and the Mineralogical Society was held in Ann Arbor, Mich., May 11. About sixty members attended.

An interesting demonstration of the use of platinum-wound furnaces, which are used for determining the phase-rule diagrams of ceramic materials, was given by A. B. Peck of the University of Michigan. Dr. Peck spoke after the dinner which was held at the Michigan Union.

E. H. Kraus, also of the University of Michigan, spoke later in the evening on the subject, "Gems and Gem Cutting." Dean Kraus explained the properties necessary for minerals to become gems. He also described gem cutting as done in the Idar district of Germany, illustrating the work with slides and specimens.

—MACON C. TRABUE, *Secretary*

ST. LOUIS SECTION MEETS AT ROLLA

The St. Louis Section of the American Ceramic Society held its spring meeting in Rolla, Mo., Saturday, May 18.

During the morning, open house was held in the laboratories of the Ceramic Department, Missouri School of Mines and Metallurgy, where O. W. Kamper demonstrated the results of his thesis, "The Electrical Lubrication of Dry-Press Dies." Terrell Evans, who has been working with N. W. Coffman on an FERA pottery project, demonstrated the use of Missouri stoneware clay in turning pottery. Considerable interest was shown by the visitors in the X-ray microscope equipment of the U. S. Bureau of Mines which was explained by Donald Doan and S. R. B. Cooke.

The department's new electrically heated hot load-test furnace was in operation during the morning.

The group, including the visiting ladies, had luncheon at the Pennant Tavern where they were entertained with dance numbers by pupils from the Kay Haymes School of Dancing.

The program of the afternoon was as follows:

(1) "Activities of the Ceramic Department," by C. M. Dodd, Acting Head, Ceramic Department.
(2) "Mining by the Block-Caving System," by J. H. Steinmesch, Head, Mining Department.
(3) "Manufacture of Insulating Brick," by R. S. Bradley, A. P. Green Fire Brick Co.
(4) "Problems Connected with Tunnel-Kiln Operation," by C. A. Smith, Mexico Refractories Co.
(5) "The Geological Occurrence of Missouri Halloysite," by H. S. McQueen, Assistant State Geologist.
(6) "Missouri Halloysite as a Refractory Raw Material," by F. J. Zvanut, Graduate Assistant, Ceramics Department.
(7) "An Open Discussion on Glass-House Refractories," J. W. Wright, leader, Owens-Illinois Glass Co.

Group discussions followed each paper.

The following companies were represented at the meeting by:

Owens-Illinois Glass Co., Alton, Ill.: J. W. Wright, *St. Louis Section Chairman.*

A. P. Green Fire Brick Co., Mexico, Mo.: L. J. Miller, R. S. Bradley, G. R. Sullivan, *R. S. Green, *C. A. Freeman, *Wm. R. Powell, *Joe E. Stevens, *J. J. Offutt, E. B. Hunt, Cyril Bradwell, and *Ben K. Miller.

Harbison-Walker Refractories Co., Fulton, Mo.: A. H. Jordan and Frank Catalina.

* Graduates and former students at Missouri School of Mines.

Harbison-Walker Refractories Co., Vandalia, Mo.: C. C. Hardy, Clyde M. Evans, John J. Hazel, *H. L. Harrod, *H. R. Herron, *A. R. Maune, and *F. J. Louney.
Laclede-Christy Clay Products Co., St. Louis, Mo.: H. E. Johnson and A. Benn.
Mexico Refractories Co., Mexico, Mo.: C. A. Smith.
Walsh Refractories Co., Vandalia, Mo.: Fred H. Schwetye.
Chas. Taylor Sons Co., Cincinnati, Ohio, and Armstrong Cork Products Co., Pittsburgh, Pa.: *K. I. Gannon.
St. Louis Pottery, St. Louis, Mo.: August Vollmer, Jr.
Missouri Geological Survey, Rolla, Mo.: H. S. McQueen.
Missouri School of Mines and Metallurgy, Rolla, Mo.: J. H. Steinmesch, C. M. Dodd, F. J. Zvanut, C. H. McDonald, O. W. Kamper, E. L. Dudley, E. Frauenfelder, W. G. Twyman, R. M. Springer, A. J. Hoener, Paul C. Branstetter, and Stuart Dods.

Mr. Wright outlined plans for the Section's fall meeting to be held in St. Louis, for which a program of general interest to all branches of ceramics will be arranged.

—C. M. Dodd

NORTH CAROLINA SCHOOL NEWS

John W. Whittemore, head of the Department of Ceramic Engineering at Virginia Polytechnic Institute, Blacksburg, Va., has been elected an honorary member of Keramos, professional ceramic engineering fraternity, by the chapter at the University of North Carolina. Before going to V.P.I., Prof. Whittemore was head of the Department of Ceramic Engineering at Louisiana State University.

The Department of Ceramic Engineering at the Raleigh Unit of the University of North Carolina was given the General Excellence Award for its exhibit of art pottery at the annual Dogwood Festival held in April at Chapel Hill, N. C.—A. F. G.-W.

NEW YORK STATE COLLEGE OF CERAMICS STUDENT BRANCH

By recent action of the Board of Trustees of the University, all engineering students of the Ceramic College must become active members of the Student Branch of the American Ceramic Society. The membership consists of 204 engineers. The officers are Andrew J. Fedor, *President;* P. P. Adessa, *Vice-President;* E. S. Perkins, *Treasurer;* and W. S. Hawkes, *Secretary.*

At the monthly meetings of this organization, the following speakers have addressed the students: N. W. Taylor, Pennsylvania State College, head of Department of Ceramic Engineering, "The Nature of Glass"; T. S. Curtis, Curtis Laboratories, Huntington Park, Calif., "Modern Trends in Ceramics"; Donald Hagar, Consulting Engineer, Zanesville, Ohio, "Raw Materials in the Ceramic Industry."

L. E. Barringer of the General Electric Company and Chairman of the Art Division of the Society addressed the members of the Ceramic Guild (members of the Ceramic Art Department) on "Who Will Do the Work One Hundred Years from Now?"

The Order of St. Patrick, patron saint of engineers, knighted twenty senior engineers at the annual celebration. Others receiving this honor were Ross C. Purdy, General Secretary of the American Ceramic Society; C. Forrest Tefft, Claycraft Co., Columbus, Ohio; Roland J. Clark, Ceramic Engineer, Dayton, Ohio; and J. J. Merrill, N. Y. State Tax Commissioner, who was active in founding the Ceramic College.—W. S. Hawkes, *Secretary.*

NATIONAL BRICK MANUFACTURERS RESEARCH FOUNDATION

REPORT OF COMMITTEE ON REVISION OF THE CONSTITUTION AND BY-LAWS

Henry C. Kleymeyer, *President:*

The Special Committee on Revision of the Constitution and By-Laws hereby submits the following report:

Whereas, the words "National Brick Manufacturers" in the name of our Research Foundation has caused misunderstanding and tends to limit the scope of our Research Program which is intended to include all Structural Clay Products, and

Whereas, the plan of joint memberships with the American Ceramic Society has caused confusion and has failed to produce the joint support and close affiliation desired, therefore be it

Resolved, that all of the present Constitution and By-Laws be annulled, and the following be substituted therefor:

By-Laws of the Structural Clay Products Research Foundation

Article I. Name

This Corporation shall be known as the STRUCTURAL CLAY PRODUCTS RESEARCH FOUNDATION.

Article II. Purpose

This Foundation shall be organized as a corporation not for profit, with the following purposes:

(1) To initiate, foster, conduct, and direct research in the fields of, and to collect, codify, distribute, and promulgate data pertaining to the manufacture, production, properties, and uses of structural clay products.

(2) To secure the necessary funds, equipment, and services to accomplish the foregoing objects.

(3) To secure, hold, and disburse endowments to as-

sure the continuity of its operations and perpetuate its objects, and all things incidental to the foregoing.

Article III. Affiliation with the American Ceramic Society

Section 1: In order to promote the closest coöperation between the Foundation and the American Ceramic Society, the chairmen of the Structural Clay Products, Terra Cotta, and Materials and Equipment Divisions of the Society shall be members of the Board of Trustees of the Foundation, as provided in Article IV ofthese By-Laws.

Section 2: Reports of Research conducted by the Foundation, which may be released by its Board of Trustees, shall be available to the Program Committee of the Structural Clay Products Division of the Society for presentation at the meetings of the Division.

Section 3: In consideration of the representation provided the American Ceramic Society in Article III, Section 1 of these By-Laws. All reports and bulletins of the Foundation, which may be released for publication by its Board of Trustees, shall be printed by the American Ceramic Society without cost to the Foundation, unless compensation therefor shall be mutually agreed upon.

Article IV. Administration

Section 1: *Trustees.*—The affairs of the Foundation shall be directed by a Board of Trustees consisting of nine members.

Three members of the Board of Trustees shall consist of the Chairmen of the Structural Clay Products, Terra Cotta, and Materials and Equipment Divisions of the American Ceramic Society, who shall be elected each year to serve one year by the members of the Division, in accordance with the By-Laws of said Division.

Two members of the Board of Trustees shall be elected each year for a term of three years by the other members of the Board of Trustees of this Foundation at the Annual Meeting.

For the year 1935, the six members of the Board of Trustees, besides the three officers of the Structural Clay Products Division, shall be elected, two each for terms of one, two, and three years, respectively, by the Board of Trustees of the National Brick Manufacturers Research Foundation (which corporation this Foundation continues by change of name and amendment of the articles of incorporation, constitution and by-laws) as soon as possible after the adoption of these revised by-laws. The Board of Trustees of the National Brick Manufacturers Research Foundation shall terminate as soon as said election is completed.

Section 2: *Officers.*—The officers of the Foundation shall be a President, a Vice-President, a Secretary and a Treasurer, who shall be elected by the Trustees at the Annual Meeting, for a term of one year, or until their successors shall have been elected and qualified.

Section 3: *Meetings.*—The Board of Trustees of the Foundation shall hold the Annual Meeting at the place and during the time of the Annual Meeting of the American Ceramic Society. Other meetings may be held at their discretion.

Section 4: *By-Laws.*—The Board of Trustees shall be governed by these By-Laws, and such amendments thereto as shall be adopted in accordance with Article VI.

Section 5: *Executive Committee.*—The officers of the Foundation shall constitute an Executive Committee, which shall manage the affairs of the Foundation under the direction of and subject to the approval of the Board of Trustees.

Article V. Research

Section 1: *Research Committees.*—The Research Work of the Foundation shall be carried on by Research Committees authorized by the Board of Trustees.

Section 2: *Committee on Research Committees.*—The Board of Trustees shall appoint a Committee on Research Committees, which shall select the personnel, plan the program, and supervise the work and publications of all Research Committees, subject to the approval of the Board of Trustees.

Section 3: *Personnel of Committees.*—In selecting the personnel of the Committee on Research Committees and of each Research Committee, representation shall be given to the producing, technical, and consuming interests concerned, but the majority of each committee shall represent the technical and consuming interests.

Article VI. Amendments

These By-Laws may be amended by two-thirds vote of the Board of Trustees at any regular or called meeting, provided notice of such proposed amendment has been filed with the Secretary and sent to all members of the Board of Trustees at least two weeks previous to such meeting.

Respectfully submitted,
Committee on Revision of Constitution and By-Laws
(Signed) DOUGLAS F. STEVENS, *Chairman*
CULLEN W. PARMELEE
C. FORREST TEFFT

ENAMEL DIVISION PROPOSES AMENDMENTS TO THE BY-LAWS

Proposed Amendments

IV. Officers

(1) (Beginning third sentence) now reads: "The officers and two councilors of the Division shall be elected annually by ballot at the last session of the Division held during the Annual Meeting of the Society and shall take office at the close of the meeting at which they are elected. The Chairman shall not be eligible for immediate reëlection."

It is proposed that this section be changed to read (beginning third sentence): "The officers and two of the councilors of the Division shall be elected annually at the last session of the Division held during the Annual Meeting of the Society, the officers for one year and the councilors for two years. The officers and councilors shall take office at the close of the meeting at which they are elected. Two

of the four councilors shall be holdovers from the previous year. The Chairman shall not be eligible for immediate reëlection."

(2) Now reads: "All vacancies occurring during the year shall be filled by appointment by the Executive Committee, and a person so appointed shall not forfeit the privilege of subsequent election to the same office."

It is proposed that this be changed to read: "All vacancies occurring during the year shall be filled by appointment by the Chairman, subject to the approval of the Executive Committee. Should the Chairmanship become vacant, a new Chairman shall be chosen by the Executive Committee, the Division Secretary conducting the poll. The new Chairman so chosen shall not forfeit the privilege of election to succeed himself at the next regular election of officers."

VI. Division Nominating Committee

(Beginning last sentence) now reads: "The nominations shall be announced to the Division by letter not later than forty-five days before the Annual Meeting."

It is proposed that this be changed to read: "The nominations shall be announced to the Division by publication in *The Bulletin of the American Ceramic Society* in an issue not later than that of the month preceding the Annual Meeting."

VII. Standing Committees

Now reads: "The following Standing Committees shall be appointed each year by the Division Chairman: Membership, Rules, Standardization of Tests, Research, Data, and Education. The Chairman of each of these Committees shall act as the Division representative on the Society's General Committee."

It is proposed to add (after first sentence): ". . . .and the Committee on Program and Papers."

VIII. Special Committees

Now reads: "The Chairman of the Division shall appoint such additional committees as he may deem necessary, all committee appointments to be subject to the approval of the Executive Committee."

It is proposed that this be changed to read: "The Chairman of the Division shall appoint such additional committees as he may deem necessary. The appointment of the Chairman of each special committee shall be subject to the approval of the Executive Committee of the Division."—R. D. LANDRUM, *Chairman*,
Rules Committee, Enamel Division

NOTES AND NEWS

ILLINOIS GLASS CONFERENCE PROGRAM

The third Conference on Glass Problems held May 31 and June 1,1935, under the auspices of the Dept. of Ceramic Engineering, University of Illinois, and the Chicago Section of the American Ceramic Society, dealt with the following topics:

"The Use of Cullet in the Glass Industry" by C. J. Uhrmann, Peltier Glass Co., Ottawa, Ill.

This was followed by a report on the questionnaire submitted to the glass industry regarding the use of cullet, presented by C. W. Parmelee.

"Heating Up a Glass Tank Furnace" by Z. C. Kline, Niles Glass Works of General Electric Co., Niles, Ohio.

"Application of Special Refractories in Glass Furnaces" by M. C. Booze, Chas. Taylor Sons Co., Cincinnati, Ohio.

"Report of Progress in Glass Research in the Department of Ceramic Engineering" by C. W. Parmelee, Dept. of Ceramic Engineering, Univ. of Ill.

This summary dealt with the effects of alumina on the following properties of glass: rate of melting (W. B. Silverman); scratch hardness of surface (K. C. Lyon); thermal expansion (J. J. Theodore); surface tension (C. G. Harman); tensile strength (A. E. Badger and W. B. Silverman); and general melting phenomena (W. S. Debenham).

"The Principles of Heat Transmission and Insulation of Furnace Walls" by R. K. Hursh, Dept. Ceramic Engineering, Univ. of Ill.

"Insulation of High-Temperature Furnaces" by R. S. Barber, Johns-Manville Co., Chicago, Ill.

"Considerations in Applying Insulation" by R. S. Moore, Harbison-Walker Refractories Co., Pittsburgh, Pa.

"Insulation of Glass-Furnace Regenerators" by J. E. McBurney, Owens-Illinois Glass Co., Alton, Ill.

This was followed by a report on the questionnaire submitted to the glass industry regarding furnace insulation, presented by A. E. Badger.

On the evening following the first session, the group gathered at an informal dinner, which was followed by a lecture by A. R. Cahn of the University of Illinois, whose topic was "The Land of the Midnight Sun." This was illustrated by colored motion pictures.

—C. W. PARMELEE

CERAMIC SUMMER SCHOOL AT ALFRED UNIVERSITY

From July 1 to August 9, 1935, the New York State College of Ceramics of Alfred University will offer courses in ceramic art, glass technology, enamels, X-ray analysis, petrography, whiteware technology, and the general technology of ceramic materials and products.

The work will be given by the regular staff of the college and all the library and laboratory facilities of the institution will be available. Detailed information may be obtained by writing to W. A. Titsworth, Director of the Summer School, Alfred, N. Y.—M. E. HOLMES

SEVEN CERAMISTS GIVEN PROFESSIONAL DEGREE AT OHIO STATE UNIVERSITY

The following ceramists received the professional degree of Ceramic Engineer from Ohio State University in 1935; the titles of theses presented to fulfill requirements for this degree are also given below:

Barger, Harold D. (B.Cer. E. 1916) Ohio Representative, Wellsville Fire Brick Co., Wellsville, Mo. "The Effect of a Malleable Iron Slag on Firebrick Side-Wall Brick."

Blewett, John B. (B.Cer.E. 1916) Superintendent, McLain Fire Brick Company, Wellsville, Ohio. "Development and Operation of a Clay Mine in the Lower Kittanning Vein."

Duncombe, Geo. H., Jr. (B.Cer.E. 1915) Research Engineer, National Aluminate Corp., Chicago, Ill. "The Results of Application of Induced Draft for Water-Smoking in Sewer-Pipe Kilns."

Gerber, Albert C. (B.Cer.E. 1915) Superintendent, Plant No. 2, General Ceramics Co., Metuchen, N. J. "Development of a Successful Periodic Humidity Drier for Grog Ware."

Hill, Ercill C. (B.Cer.E. 1911) Research Engineer, The Abrasive Co., Philadelphia, Pa. "Ceramic Treatment of Garden Pottery."

Simmons, Ralph W. (B.Cer.E. 1914) Superintendent, Pittsburgh Plate Glass Plant No. 6, Ford City, Pa. "The Manufacture, Fabrication, and Setting of Carrara Structural Glass."

Sproat, Ira E. (B.Cer.E. 1911) Manager of Ceramic Division, R. T. Vanderbilt Company, New York. "The Use of Pyrophyllite in Wall-Tile Bodies."

INDUSTRIAL ADVISORY COMMITTEE ON REFRACTORIES TO THE NATIONAL BUREAU OF STANDARDS FORMED

An Industrial Advisory Committee on Refractories to the National Bureau of Standards, with representatives from eight companies manufacturing refractories and one from the Refractories Fellowship at Mellon Institute has been formed to keep the members of the refractories industry in contact with current research studies and testing work on refractories, and to suggest and discuss problems for future research dealing with refractory materials.

The first meeting of this committee was held at the Bureau on April 24. Those attending were C. E. Bales, Ironton Fire Brick Co., Ironton, Ohio; R. S. Bradley, A. P. Green Fire Brick Co., Mexico, Mo.; F. A. Harvey, Harbison-Walker Refractories Co., Pittsburgh, Pa.; J. M. McKinley, North American Refractories Co., Cleveland, Ohio; S. M. Phelps, American Refractories Institute, Pittsburgh, Pa.; L. J. Trostel, General Refractories Co., Baltimore, Md.; P. H. Bates and R. A. Heindl, National Bureau of Standards.

The organization of the Bureau, its relation to the government departments, its contacts with the producing and consuming public, and the funds available for research on refractory materials were explained in considerable detail by P. H. Bates, Chief of the Division of Clay and Silicate Products. The Committee raised objections to certain tests made in connection with the routine testing of refractory materials.

Various activities of the Refractories Section of the Bureau were described and the results of current investigations were given by the workers engaged in the studies.

—R. A. Heindl

NORTH CAROLINA SCHOLARSHIP CUPS AWARDED

Thomas L. Hurst of Leonia, N. J., was awarded the J. C. Steele Scholarship cup at the annual Scholarship Day exercises at the Raleigh unit of the University of North Carolina, April 17. This cup, the highest scholarship award in the Department of Ceramic Engineering is given each year to the student having the highest scholastic average in the three upper classes.

Mr. Hurst was also awarded the cup in 1934, and in 1933, as a freshman, he won the Moland-Drysdale cup.

W. W. Gaskins of New Bern, N. C., received the Moland-Drysdale Scholarship Cup, awarded each year to the freshman in the department having the highest scholastic average.

The J. C. Steele cup is the gift of the J. C. Steele & Sons Company of Statesville, N. C., and commemorates the establishment by J. C. Steele of the first plant in the South for the manufacture of ceramic machinery.

The Moland-Drysdale Cup was presented to the department by the company of that name located at Hendersonville, N. C. This company is one of the largest manufacturers of structural clay products in western North Carolina.

POSTE LECTURES ON ENAMELS

Emerson P. Poste, Consulting Chemist of Chattanooga, Tennessee, gave a series of lectures and demonstrations on enamels, April 29 and 30, in the Ceramic Engineering Department of the Georgia School of Technology, Atlanta, Georgia. The lectures were illustrated by motion pictures and accompanied by demonstrations in the laboratory. In this work, the actual manipulations of producing satisfactory ground and cover coats for cast iron and steel were accomplished by the students under the direction of Mr. Poste.

The sessions were attended by the students of the Ceramic and Chemical Engineering Departments and others of the student body and faculty interested in enamels.

—A. V. Henry

Special Librarians' Convention Held in Boston

The Special Libraries Association held its twenty-seventh annual convention in Boston, June 11 to 14. Visits to the special libraries of Harvard University, Massachusetts Institute of Technology, and others in the Boston area were made. The ceramic industry is represented in the science-technology group by Catherine G. Deneen, Librarian at the Corning Glass Works, Corning, N. Y.

DRESSLER TUNNEL KILNS' GENESIS*

By Conrad Dressler

Note: As a misleading account of the early history of the Dressler Tunnel Kiln[1] has appeared in *The Bulletin of the American Ceramic Society*, I have been asked to give a statement of the facts, and I do so with the more pleasure as I have many kind friends in the States who will be interested in knowing the genesis of this invention.
—The Author

I first became interested in pottery, particularly in Della Robbia ware, as a student at the South Kensington Museum, and as far back as 1888 had built a little muffled kiln in my studio in Chelsea, in which I fired and enameled terra cotta plaques and reliefs. I was encouraged in this by the example of William De Morgan, a famous English potter. Later on, he fired pieces for me, as my small kiln was not equal to very important work.

In 1895 I moved south to Marlow in Buckinghamshire and established the Medmenham Potteries, assisted financially by R. W. Hudson. I had made the acquaintance of Louis and Achille Parvillée, two brothers whose work in France I greatly admired.

The elder brother undertook to build me an oven in which to fire my prospective work. Later on he also built two small muffle kilns.

In 1908–1909, I formed a little company among my friends for the purpose of manufacturing tile. I again asked Achille Parvillée to design my kiln. At that time Mr. Parvillée had developed a scheme for firing porcelain insulators in a series of intermittent kilns which were connected by underground flues so that the products of combustion from the one were drawn into the next to preheat the goods, while the air for combustion was drawn through the cooling kiln preceding the one being fired to recuperate some of the heat which else would have been wasted. This was a novelty at the time and a great advance on previous practice.

I suggested to my friend that it would be better to pass the ware, loaded on trucks, through a tunnel kiln. Tunnels had been tried for almost a century but somehow had nearly always been abandoned. I knew, however, that a Mr. Faugeron, of Montereau, France, had succeeded in using a tunnel for general ware. I had also heard that a tunnel was successfully used in Germany. I tried to see the latter but was denied an entrance to the works. I knew Mr. Bock, a well-known kiln builder in Berlin, who had built tunnel kilns and was the inventor of the sand seal. He was not very encouraging, telling me plainly that he had abandoned them, owing to the many difficulties they presented.

Nevertheless I insisted, and my friend designed for me a tunnel kiln, 120 feet long about 4 ft. wide and 5 ft. 6 in. high internally, in which to fire my tile on trays.

This kiln was built at Northolt, a suburb of London, at the brickworks of A. Frazer, who was the chairman of my company. The fuel which we proposed using was waste oil, then to be obtained fairly cheaply; Mr. Parvillée came over from France to light up the kiln, but his efforts to fire the goods were vain; he could not obtain the oxidizing atmosphere needed at the critical point, namely at the hottest place. All the goods came out spoilt.

I then urged him to use clean producer gas, with which he was familiar. He reluctantly agreed to try this, feeling that the problem was a more delicate one than he had expected. However, I was very determined not to give up the idea, and whilst he was away on the Continent, I purchased a Mond gas producer and installed the gas ducts according to his design.

It was in the early summer of 1909 that this work was being done. Before it was quite completed I received a telegram from France informing me that my friend had been killed in the terrific explosion of the large gas holder of the Geneva Gas Works.

This was appalling news for me and for my stockholders. We held a meeting and I was asked whether I would undertake to see the matter of the kiln through. I said that I would try, provided that I could count upon their backing.

I then completed the gas installation and, having lighted up, I found that exactly the same troubles appeared as with the oil system. I now saw that I had to face the whole problem, which had baffled so many before.

My first idea was to muffle the kiln, if I could, which meant reducing the area for the goods. Of course, I knew that I would have to contend with varying expansions, for these exist in all muffles and account for their rapid deterioration. I tried to provide for these expansions but found that this was impossible. The inner shell buckled so that the goods could not travel through the oven without hitting the sides.

It was then that I had the happy thought that if, instead of struggling against natural phenomena like that of varying expansions, I accepted them, I should meet the difficulty. My idea was to place a chamber in the form of one or several tubes prone on a sanded bench, on each side of the traveling goods, and allow it to lengthen out at its own natural rate of expansion whilst the body of the kiln expanded at a lesser rate, in sections provided with expansion joints.

I started first with a multiple drain-pipe system, six altogether on each side in pairs, supported by blocks resting on a platform covered with refractory sand.

The expansion I found took place normally, but I soon discovered that these pipes were not practical; they bent in the hottest place.

I then went to a single square chamber with internal cross-ties. These chambers had walls that were too thick; the heat accumulated in these walls. The ties also were a source of trouble; they melted and pulled down the sides.

By this time I had learned the lesson. The chambers must have walls as thin as possible and be shaped of a section somewhat triangular, with suitable curves, however, to resist stresses and strains.

I had more or less anticipated these needs so that I was able to follow up my experiments rapidly. Had I not done so I do not believe that my Board of Directors would have allowed me to go on. The kiln was altered and changed from its original design six times in a drastic and

* Received April 11, 1935.

[1] Charles J. Kirk, "The Dressler Tunnel Kiln's Early History," *Bull. Amer. Ceram. Soc.*, **13** [11] 325–26 (1934).

complete way and quite fifteen times in minor details.

Within a year of the death of Parvillée I had secured the first results. I had abandoned the producer first installed in favor of an ordinary brick-built coke producer. With this I had ample heat, and the goods began to come through in perfect condition.

I now determined to invite a number of Staffordshire potters as well as scientific journalists, among them the *Times* correspondent of their weekly engineering number, to a demonstration. My anxiety can be imagined, for I had to ask them quite eight days in advance; would the kiln still be running when they came?

Fortunately everything went off well. The meeting was a great success and the various reports were very favorable and encouraging.

I was soon able to secure a first order for an industrial kiln from J. H. Barratt Co. of Stoke-on-Trent. This, my first kiln, was a complete success and is still giving the best service after 23 years of continuous running.

This was followed by an order from Pearson & Co., Chesterfield, manufacturers of stoneware jampots. Here I had to deal with a considerably higher temperature (1250°C instead of 1050°C) and I had the mortification to find that although I used the best refractories available in England (Glenboig aluminous fire clays), the chambers did not stand up for more than a few weeks.

I tried Morgan's bauxite refractories with no better result. Whilst examining these aluminous clays in the shape of brick, which had been used in the hottest part of the furnaces in which steel was melted at 1500°C, I noticed the indentations left by the iron pincers with which the crucibles had been drawn. Removing about $^1/_4$ inch of the surface which so evidently had been soft at the time, I found the substance of the brick quite unaffected. This brought me to the conclusion that long before the clay fused it started to soften, though not to the point of collapsing as long as it was supported and kept up by the backing of the hard substance behind.

The conditions of my combustion chambers were these: In order to produce a temperature of 1250°C in the body of the kiln, I needed a potential of heat in the combustion chamber which might easily result in a temperature of 1550°C. Now the 1250°C would probably leave the fire clay stiff and hard like iron, but the 1550°C would make it soft and pliable like lead. My purpose now was to support the surface liable to become soft at as many close points as possible by a rigid framework. This lead me to the idea of double walls with intervening partitions, in fact, to the use of hollow tile such as is used quite commonly in the building trades, but of proportions suited to my purpose and of a very highly refractory material.

I built my chambers out of four sections of such tile of a shape suitable for housing them in the arch of the tunnel and balanced so as to give the greatest possible stability. This structure gave excellent results; the chambers now stood up many months instead of weeks, and eventually they came to stand for two or three years without the need of change.

Another advantage was secured by this double-walled structure: The goods were screened from the excessive heat, which was poured out of the inner wall of the combustion chamber by its outer wall, and the space available on the truck for goods was doubled, whilst the distribution of the heat became uniform all over the truck load, provided the heating zone was long enough.

To lengthen it, I introduced the gas at two or more points on each side, and, in order that this should be possible, I invented and installed suitable by-passes or hoods in which the gas and air could be completely mixed before joining the stream of burnt gases.

The next step forward was in the use of silicon carbide as a refractory for my chambers. The first set of these was manufactured by Dr. North of Hannover, Germany, and fortunately reached the coast of England on the day war was declared. This set was used at Pearson's and gave excellent results, so that in most high-temperature ovens this material has been used ever since.

By this time I had built four ovens in England, two in Belgium, and one in Germany.

The war stopped my operations.

About two years before, I had read a paper before the British Ceramic Society at Stoke-on-Trent, describing my original invention. In September, 1914, I gave another paper showing the progress that had been made in the interval. This was duly published in the Society's *Transactions*.[2] A number came under the eye of Charles Kirk, President of the Universal Sanitary Company of New Castle, Pa., who was at that time pioneering the casting process for making sanitary ware in the United States and looking for further methods for reducing costs. He suggested to W. S. Kupfer, who was considering joining him in partnership, that, with a Dressler tunnel kiln saving him some 75% in fuel and about as much in labor, he would be in a position to make a good profit in spite of prevailing low prices. Mr. Kupfer wrote to my company for information about the kiln, expressing the desire to have one built. It was decided that I should go over to the States to clinch the matter. This was in the late spring of 1915. I went and having seen the site, which unfortunately was somewhat limited in length but which was imposed upon me, I designed the kiln and erected it. The results were not at first satisfactory. The kiln was too short. The goods had not the time needed in which to cool without dunting. I also had trouble with natural gas, with which fuel I was not acquainted. I had to make a special burner of silicon carbide so as to burn it without its cracking.

I returned to the States in the late summer of the same year. I obtained leave to lengthen the kiln and the dunting trouble was overcome.

A meeting of the American Ceramic Society took place in the autumn of 1915 to view the kiln, and so well pleased were its members with what they saw that in the following spring when I returned I took orders for several kilns and finally sold the American rights to W. S. Kupfer, who formed a company under the title of the American Dressler Tunnel Kilns.

PARIS, FRANCE

[2] For more detailed technical account of the development described above see *Trans. Ceram. Soc.* [England]:
(1) Conrad Dressler, "A New Tunnel Oven," **11,** 38–55 (1911–12).
(2) Conrad Dressler, "Development of Dressler Tunnel Oven Since 1911," **14,** 41–61 (1914–15).
(3) Conrad Dressler, "The Dressler Tunnel Oven and Its Application to the Heat Treatment of Steel," **16,** 171–88 (1916–17).

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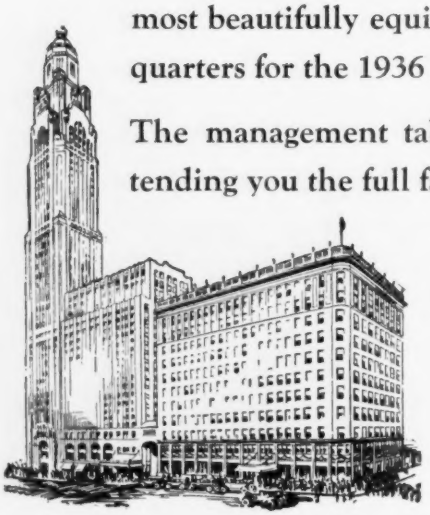

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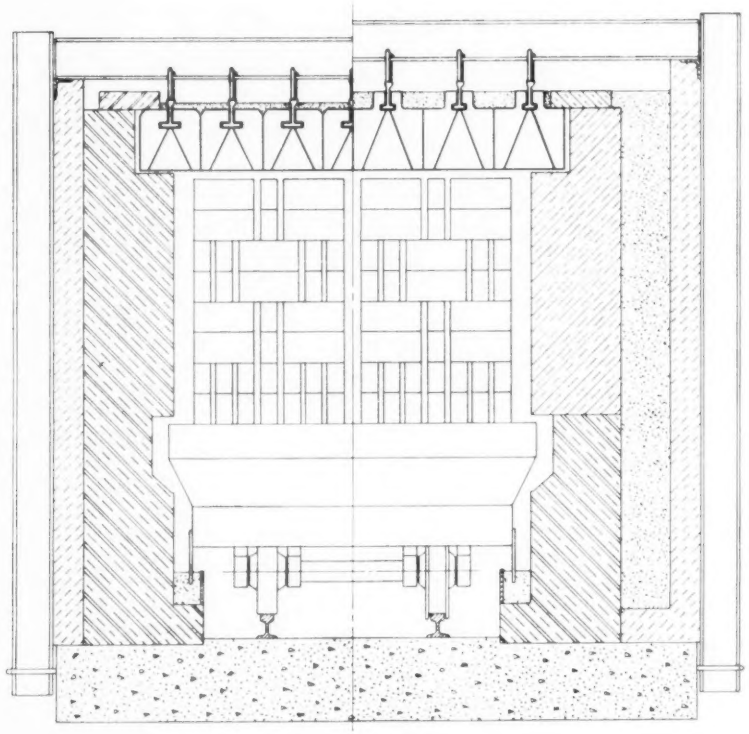

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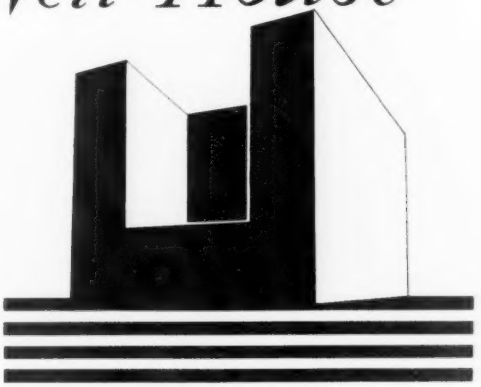

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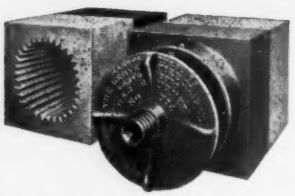

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Pete Potter

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